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PALEONTOLOGY

Volume 30 SEPTEMBER, 1956 Number 5

JOURNAL OF PALEONTOLOGY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation of* The American Association of Petroleum Geologists *and* The Geological Society of America

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The JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

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Entered as second-class matter at the Post Office at Tulsa 1, Oklahoma, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R, authorized April 3, 1935.

Additional entry as second-class matter at the Post Office at Menasha, Wisconsin.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 30 | SEPTEMBER, 1956 | NUMBER 5

OSTRACODA OF THE SILURIAN DECKER AND MANLIUS LIMESTONES IN NEW JERSEY AND EASTERN NEW YORK

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ABSTRACT—Descriptions and illustrations are given for 44 ostracode species of the Decker, Rondout and Manlius limestones of the William Nearpass quarries and Dalton Nearpass farm in northwestern New Jersey, and at Austin's Glen and Trilobite Mountain in New York. One brachiopod variety is proposed. The ostracode species are distributed through 11 families and 23 genera. Thirty-two species and one variety are new, and there are eight new genera. Holotype or syntype specimens of 13 of Weller's ostracode species have been restudied and are refigured and redescribed. Stratigraphic sections are described to provide details of the ostracode occurrences, and zonal potentialities are considered. There is an extensive and distinctive suite of ostracode species in the uppermost part of the Decker limestone, and at least one well characterized species occurs in middle beds. Species of *Leperditia* are common in the Rondout limestone, where other observed ostracodes include only some unidentified specimens of *Kloedenella* and more questionably of *Eukloedenella*. Ostracodes are numerous and diversified in the Manlius limestone, and include several distinctive species that range throughout the formation, whereas others are restricted to lower, upper, and possibly middle beds. Successive changes of the ostracode assemblages and other faunal groups in part are evolutionary, but in part reflect modifications in environment that affected the animal communities as a whole.

New genera described are: *Bonneprimites, Limbinaria, Pseudobeyrichia, Lophokloedenia, Myomphalus, Welleriopsis, Saccarchites, Thlipsuropsis.* New species (genotypes marked with asterisks) are: *Bonneprimites? breviformis, Aechmina eupunctella, Limbinaria multipunctata*, L. paucipunctata, L. biangulata, Richina zygalis, Parabolbina cuneospinosa, Velibeyrichia reticulosaccula, V. paucigranulosa, Dibolbina macrosulcata, Pseudobeyrichia perornata*, Kloedenia duplicipunctata, K. crassipunctata, K. aparchoides, Lophokloedenia eufimbriata, Myomphalus dorsinodosus*, Welleriopsis diplocystulis*, Mesomphalus rhomboidalis, M. striatellus, Saccarchites saccularis*, Bolbiprimitia limbata, B. teresaccula, Euklo edenella cicatrix, E. manliensis, Kloedenella bipustulata, K. parvisulcata, Dizygopleura angustisulcata, Thlipsuropsis diploglyptulis*, T. longisulcata, T. digitata, Parahealdia? convexoris;* new varieties are: *Welleriopsis jerseyensis* var. *microreticulis, Chonetes jerseyensis* var. *nondivergens.*

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INTRODUCTION AND ACKNOWLEDGMENTS

FAUNAS of the successive Decker, Rondout and Manlius limestones of the old William Nearpass quarries in northwestern New Jersey, were described a half-century ago by Stuart Weller (1903) to furnish an important milestone in study of the Late Silurian stratigraphy and paleontology of the Appalachian region.

Ostracoda are numerous in some of the Decker-Manlius beds. Fifteen ostracode species from these strata were recognized by Weller, in association with larger assemblages of corals, bryozoans, brachiopods, mollusks and trilobites. Further promise that ostracodes will be invaluable for zonation and correlation of the Decker-Manlius sediments became apparent with discovery of numerous highly ornamented specimens in collections obtained by F. M. Swartz near Catskill, New York in 1929, and at the William Nearpass quarries and Dalton Nearpass farm in New Jersey in 1937.

As a step in establishing characters and ranges of the ostracode species, arrangements were made in 1939 for restudy and reillustration of Weller's type specimens, and work was also begun on part of the new collections. Loan of Weller's ostracode types was secured through the kindness of Meredith E. Johnson, State Geologist of New Jersey. The collections from the Manlius at Austin's Glen were obtained under the cordial guidance of George H. Chadwick during a trip sponsored by the Pennsylvania Geological Survey. The Nearpass section was studied during a visit with A. B. Cleaves to eastern Pennsylvania and adjoining areas, also supported by the Survey. Specimens investigated in the early part of the study were in part photographed by F. M. Swain under a grant-in-aid from the Council on Research of The Pennsylvania State University, and were described at that time by F. C. Whitmore, Jr., in his Master's thesis. About half of the photographs have been prepared in more recent years by F. M. Swartz.

The type specimens of Weller's ostracode species are housed among collections of the New Jersey Geological Survey at Newark, New Jersey. Types of new species together with numerous other mounted specimens are retained at present in the mounted fossil collections of F. M. Swartz at The Pennsylvania State University, University Park, Pennsylvania, but will at a future date be offered to the United States National Museum, Washington.

CORRELATION PROBLEMS OF THE DECKER, RONDOUT AND MANLIUS LIMESTONES OF NEW JERSEY

In the half-century since publication of Weller's studies, correlation of the Decker, Rondout and Manlius limestones of New Jersey has been subject to varying opinions. Problems still remain that probably can be benefited by tracing zones of the ostracodes now recognized in the Nearpass quarries and Austin's Glen areas, as well as by work with additional new ostracode species.

Using corals, brachiopods and trilobites, Weller in 1903 correlated the "Decker Ferry" or Decker formation with the "Coralline" or Cobleskill limestone of east-central New York. Following the opinion of James Hall, Weller supposed that the Cobleskill and, hence, the Decker limestone were deposited concurrently with Middle Silurian

Niagaran sediments of western New York; but he called attention to marked faunal differences that he attributed to nearly complete isolation of easterly and westerly basins. The overlying Rondout limestone was correlated with part of the type Rondout limestone of the Kingston area of eastern New York. The Manlius was identified by the *Howellella vanuxemi-Tentaculites gyracanthus* fauna that distinguishes the type Manlius or "Tentaculite" limestone in central New York.

The Late and not Middle Silurian, post-Niagaran and post-Salina age of the Cobleskill and, consequently, of the Decker limestone was soon recognized independently by C. A. Hartnagel (1903) and Charles Schuchert (1903). Hartnagel traced the Cobleskill westwards in New York, and found it the essential correlate of the Late Silurian, post-Niagaran Akron dolomite of the Buffalo area. Schuchert called attention to occurrence of the Decker limestone species *Chonetes jerseyensis* in the Cobleskill limestone of New York and also in Late Silurian sediments in western Maryland that subsequently were named Keyser limestone. Hartnagel, unlike Weller, correlated only the upper part of the Decker limestone of New Jersey with the Cobleskill limestone of New York. *Halysites* and *Favosites* corals of the Cobleskill limestone, that had influenced Hall's opinion of Middle Silurian age, are recurrent due to return of favorable marine waters to New York subsequent to the Vernon-Salina interval of deposition of red and green muds, dolomites and evaporites.

A further change in interpretation, involving relations of the Nearpass quarry sequence, subsequently was advocated by E. O. Ulrich (1912). Ulrich concluded that the Decker limestone of New Jersey, and its correlatives in the lower part of the Keyser limestone of Maryland, are represented in central New York not by the Cobleskill limestone but instead by considerably younger strata included in the upper Manlius by other authors. Ulrich believed that the type Manlius of central New York needs to be redefined and restricted to beds below his supposed Decker equivalents. He further concluded that these "Decker-age" strata in central New York, the Decker-Rondout-Manlius limestones of New Jersey, and the Keyser limestone of Maryland, properly are members of the Helderberg group and belong in the Lower Devonian series.

Ulrich's interpretations of 1912 were advanced in discusion of Late Silurian and Early Devonian strata of parts of Maryland and West Virginia, and were never fully developed by presentation of factual data about the central New York succession. Unpublished work by Russel M. Logie gives much evidence that the Decker limestone of New Jersey is older than the type Manlius of central New York, and includes equivalents of the Cobleskill formation. (See notes in Chadwick, 1944.)

The present paleontologic studies were undertaken against this background of stratigraphic problems. In the Nearpass-Austin's Glen area, the ostracodes include numerous species that have very distinctive characters and that are limited in stratigraphic range. If these promising zonal ostracodes can be traced to central New York as well as southwestward to Pennsylvania, Maryland and the Virginias, they should help to place on a firmer basis the Late Silurian correlations of the region.

In the mid-Paleozoic strata in general, Ostracoda where present tend to furnish good zonation because of rapid evolutionary changes reflected in their fossil shells. By contrast, the brachiopod *Howellella vanuxemi* and the pteropod or pteropod-like *Tentaculites gyracanthus*, that characterize the Manlius limestone in central New York, appear to owe their local stratigraphic restriction to details of the paleogeographic-environmental history of the region. In Maryland and parts of the Virginias, *Howellella vanuxemi*, as currently understood, marks zones in the upper part of the Keyser limestone, the lower-middle part of the subjacent Tonoloway limestone, and sporadically in the middle part of the still lower Wills Creek shale. The zones thus are recurrent through about a thousand feet of the Upper Silurian succession. If the *Howellella vanuxemi* occurrences in the thin Manlius limestone of central New York and in the Manlius of northern New Jersey are indicative of close equivalence, the reason

apparently lies not in the short interval between creation and extinction of the species, but rather in its introduction by the same marine incursion. Varieties of *Tentaculites gyracanthus* likewise have been reported in Maryland in recurrent zones, in both the Tonoloway and Keyser limestones.

The ranges of additional zonal species of the Cobleskill-Manlius and Decker-Manlius sequences in New York and New Jersey similarly may be affected by the environmental history of the region. The ostracodes will at least give supplementary data; and, in-so-far as ostracode zones can be established on evolutionary changes in closely related species of short time ranges, they should be especially valuable in detailed correlations of the strata enclosing them.

ORDER OF DISCUSSION

Sections at the William Nearpass quarries, on the nearby Dalton Nearpass farm, and at Austin's Glen will be described to show relations of ostracode occurrences in local sequences of the Decker, Rondout and Manlius limestones. Zonal values of the ostracode species and some paleoecologic implications of the ostracode and other faunas, will then be discussed. Specific and generic descriptions are given in the section on Systematic Paleontology.

DESCRIPTION OF LOCALITIES AND SECTIONS

William Nearpass quarries.—The William Nearpass quarries section described by Weller (1903), is exposed in small hillside cuts located in Sussex County, New Jersey, near the easterly foot of Wallpack Ridge, 3 miles south of Port Jervis, New York, at about 45° 20′ 5″ north latitude, 74° 42′ 40″ west longitude in the western part of the Port Jervis quadrangle. The quarries are so inconspicuous, long abandoned and overgrown that they are not well known by the residents of the neighborhood. Nevertheless, they still provide the most complete exposures of the Decker, Rondout and Manlius limestones known to the writers in New Jersey.

Weller's account of the William Nearpass section is given below with minor modifications in descriptions of lithology, and with additional records of ostracode occurrences. Thickness figures, given to the inch by Weller, are rounded off to the half-foot. The notations concerning numbers of individuals, including (r) = rare, (c) = common, (a) = abundant, are intended to suggest degrees of abundance as roughly estimated during preparation and removal of specimens from well lithified limestone slabs, by use of a needle under a microscope.

	Thickness in feet Bed	Total
Lower Devonian		
Helderberg group		
Coeymans limestone		
Concealed.		
Medium- to thick-bedded, gray, coarsely crystalline crinoidal limestone, concealed 3 to 8 feet above base. Basal contact well defined, contrasting with the finely crystalline limestone of the Manlius formation. *Gypidula coeymanensis* fauna, with some masses of *Favosites helderbergiae*. Weller also reported: *Stromatopora concentrica, Ptilodictya lobata, Lichenalia torta, Monotrypa sphaerica, Strophеodonta varistriata, S. planulata, Strophonella punctulifera, "Rhynchonella" semiplicata, "R." transversa, Uncinulus mutabilis, Atrypa reticularis, "Spirifer" cyclopterus, Meristella laevis, Actinopteria communis, Platyceras* sp., *Tentaculites elongatus, Proetus protuberans* and *Dalmanites pleuroptyx*. In new collections from upper half: *Mesomphalus striatellus* var. (r); *Kloedenia* sp. (r)	15	15
Thickness of exposed Coeymans limestone		15
Upper Silurian		
Manlius limestone		
Medium- to thick-bedded, finely crystalline, dark bluish-gray limestone, tending to break into irregular, lumpy fragments. Makes prominent wall near top of the old, slightly recessed quarry bluff. (This is 2A26 of Weller's description.) There are a few stromat-		

	Thickness in feet Bed	Total
oporoids 2 feet below top. Weller reported: *Strophoedonta varistriata, "Rhynchonella" sp., Centronella? biplicata, Howellella vanuxemi, Orthoceras* sp., *Kloedenia montaguensis.* New collections include the following species at 1½ feet below top: *Pholidops* sp. (r), *Stropheodonta varistriata* (c), *Schuchertella* sp. (r); *Howellella vanuxemi* (c); *Kloedenia crassipunctata* (c), *K. montaguensis* (c), *K.* cf. *K. kummeli* (r), *Welleriopsis diplocystulis* (c), *Mesomphalus* sp. (r), *Eukloedenella manliensis* (c), *Kloedenella bipustulata* (c), *Dizygopleura* sp. (r), *Bythocypris* sp. (r). At 2 feet below top: *Schuchertella* sp. (r), *Stropheodonta varistriata* (c), *Howellella vanuxemi* (c), *Centronella?* sp. (r), *Megambonia aviculoidea* (r), *Loxonema?* sp. (c), *Kloedenia crassipunctata* (c), *K. montaguensis* (r), *Welleriopsis diplocystulis* (c), *Saccarchites?* sp. (r), *Phlyctiscapha?* sp. (c), *Kloedenella bipustulata* (r–c), *Bythocypris nearpassi* (r). At 3 feet below top: *Stropheodonta* sp. (r), *Howellella vanuxemi* (c), *Centronella? biplicata* (r), *Tentaculites gyracanthus* (r–c), *Pseudobeyrichia perornata* (r), *Bolbiprimitia limbata* (r), *Kloedenia duplicipunctata* (r), *K. crassipunctata* (r–c), *K. montaguensis* (c), *Lophokloedenia* cf. *L. manliensis* (r), *Welleriopsis diplocystulis* (c), *Mesomphalus* sp. (r), *Saccarchites?* sp. (r), *Phlyctiscapha?* sp. (c), *Eukloedenella manliensis* (r), *Kloedenella bipustulata* (c), *Bythocypris* sp. (r). At 7 to 9 feet below top: *Stropheodonta* sp. (r), *Schuchertella* cf. *S. interstriata* (r), *Howellella vanuxemi* (c), *Actinopteria* sp. (r), *Tentaculites gyracanthus* (c), *Bolbiprimitia limbata* (r), *B. limbata* var. *longula* (r), *Kloedenia crassipunctata* (r), *K. montaguensis* (c), *Phlyctiscapha?* sp. (r), *Eukloedenella* cf. *manliensis* (r) *Kloedenella bipustulata* (c) *Thlipsuropsis digitata* (r), *Paraheraldia? convexoris* (r), *Bythocypris* sp. (r)	12	35
Thick-bedded, dark bluish-gray, finely crystalline limestone, in part weathering to somewhat lumpy fragments. (2A25 of Weller). Weller reported: *Stropheodonta varistriata, Centronella (?) biplicata, Howellella vanuxemi, Kloedenia montaguensis* var. *smocki.* New collections include at about 15 feet below top of Manlius: crinoid stems (r), *Stropheodonta varistriata* (c), *Schuchertella* sp. (r), *Howellella vanuxemi* (c), *Centronella?*, sp. (r), *Loxonema?* sp. (c–a), *Tentaculites gyracanthus* (c), *Parabolbina cuneospinosa* (r), *Velibeyrichia reticulosaccula* (r), *Mesomphalus* sp. (r), *Kloedenia duplicipunctata* (r), *K. crassipunctata* (c), *K. montaguensis* (r), *Saccarchites sacculatis* (r), *Phlyctiscapha?* sp. (c), *Kloedenella bipustulata* (r), *Bythocypris* sp. (r). At about 21 feet below top of Manlius: *Schuchertella* sp. (r), *Howellella vanuxemi* (r), *Leperditia* sp. (r), *Lophokloedenia manliensis* (r), *Welleriopsis jerseyensis* (r)	10	23
Medium- to thick-bedded, somewhat argillaceous, dark blue, finely crystalline limestone, breaking into irregular, lumpy masses. (2A24 and 2A23 of Weller.) In upper 5 feet Weller reported: *Stropheodonta varistriata, Howellella vanuxemi, Megambonia aviculoidea, Holopea antiqua, Tentaculites gyracanthus,* undetermined cephalopod, *Leperditia alta, Lophokloedenia kummeli;* in lower 1½ feet: *Leperditia alta*	6½	13
Medium- to thick-bedded, dark blue, dense to finely crystalline limestone, breaking into lumpy fragments. (2A22 and 2A21 of Weller.) Basal contact is well defined. Stromatoporoids are common in the upper 4½ feet, rarer in basal 2 feet. In upper 4½ feet Weller reported: *Leperditia alta, Lophokloedenia manliensis;* in lower 2 feet: *Megambonia aviculoidea, Leperditia alta, Kloedenia?* sp. At 2 feet above base in new collections: cup coral (r), *Centronella?* sp. (r), *Leperditia alta* (c), *Bolbiprimitia limbata* (c), *Lophokloedenia manliensis* (c), *Welleriopsis jerseyensis* var. *microreticulis* (c), *Kloedenella* aff. *K. bipustulata* vars. (r–c), *Bythocypris* sp. (c)	6½	6½
Thickness of Manlius limestone		35

Rondout limestone

Thin-bedded, locally crumpled, argillaceous limestone or calcareous shale, with some bands of dense limestone. (2A20.) Weller reported *Leperditia alta.* In several loose slabs: *Liopteria* sp. (r)	15	39
Pethstone bed: Thick-bedded, siliceous, dolomitic limestone, weathering buff. Residue left after boiling in acid is coherent, and consists of a porous network of white, nondetrital silica. (2A19.) One of samples contains some minute, smooth-surfaced, indeterminate, questionable ostracodes	5	24
Thin-bedded, argillaceous and siliceous limestone or calcareous shale. (2A18.) Weller reported *Leperditia alta.* At 18 feet above base of Rondout: *Herrmannina welleri* (c)	5½	19
Fine-grained, light gray brittle limestone. (2A17.) Weller reported: *Hyattidina? lamellosa* (one specimen), *Herrmannina welleri.* In new collections, a thin layer near top of unit contains *Hyattidina? lamellosa* (c), *Herrmannina welleri* (c), *Kloedenella* sp. (c). In many of the *Kloedenella* specimens, as well as in some of those of the *Hyattidina,* the valves are conjoined and the enclosed space is filled with sparry calcite	2½	13½
Thin-bedded, unfossiliferous argillaceous and siliceous limestone or calcareous shale.		

	Thickness in feet Bed	Total
(2A16.)	1	11
Fine-grained, dark limestone. (2A15.) Weller reported: *Leperditia elongata.* In new collections, at 6 feet above base of Rondout: *Schuchertella interstriata* (one specimen). At 4 feet: *Leperditia altiscalaris* (c)	6½	10
Argillaceous limestone or calcareous shale, with some thin interlayers of purer limestone. (2A14.) Base poorly defined. *Leperditia* sp.	3½	3½
Thickness of Rondout limestone		39

Decker limestone

Medium-bedded, bluish-gray crystalline, sparingly crinoidal limestone in beds 6 to 10 inches thick, separated by thin shaly partings. (2A13.) Weller included beds 2A13 to 2A9 in the *Stenocisma* ("*Atrypa*") *lamellata* zone. In 2A13 he reported: *Pholidops ovata, Camarotoechia litchfieldensis* ("*Rhynchonella agglomerata*"), *Stenocisma lamellata, Whitfieldella nucleolata, Actinopteria* sp., undetermined pelecypods and gastropods, *Kloedenia deckerensis, K. sussexensis, Zygobeyrichia nearpassi, Welleriopsis jerseyensis.* In new collections at 2 feet below top of Decker: *Pholidops ovata* (c), *Rhipidomella preoblata* (r), *Schuchertella* sp. (r), *Camarotoechia litchfieldensis* (c), *Wilsonia globosa* (r), *Atrypa reticularis* (c), *Whitfieldella?* sp. (r), *Proetus pachydermatus* (r), *Otarion* sp. (r), *Calymene camerata* (c), *Limbinaria paucipunctata* (a), *Velibeyrichia paucigranulosa* (c), *Dibolbina macrosulcata* (rr), *Mesomphalus rhomboidalis* (c), *M. rhomboidalis* var. *multipunctata* (r), *Kloedenia deckerensis* (a), *K. sussexensis* (r), *Zygobeyrichia nearpassi* (c), *Welleriopsis jerseyensis* (r), *Eukloedenella cicatrix* (c), *Kloedenella parvisulcata* (c), *Dizygopleura angustisulcata* (a), *D.* cf. *D. clarkei* (r). At 3 feet below top of Decker limestone: *Pholidops ovata* (r), *Wilsonia globosa* (r), *Stenocisma lamellata* (c), *Whitfieldella nucleolata* (r), *Calymene camerata* (r), *Limbinaria paucipunctata* (c), *Bolbiprimitia* sp. (r), *Kloedenia deckerensis* (c), *Zygobeyrichia nearpassi* (c), *Eukloedenella cicatrix* (c), *Kloedenella parvisulcata* (c), *Dizygopleura angustisulcata* (c), *D.* cf. *D. clarkei* (r), *Thlipsuropsis* sp. (r), *Bythocyris* sp. (r) | 4 | 52 |
Coralline beds: Irregularly bedded limestone, breaking into lumpy masses, and containing much fragmental coralline and shell material. (2A12.) Weller reported: *Zaphrentis* sp., *Diphyphyllum integumentum, Cladopora rectilineata, Favosites pyriformis, Cyathophyllum inequalis, Halysites catenularia, Stromatopora concentrica, Cyphotrypa (Monotrypa) corrugata, Spirorbis* sp., *Pholidops ovata, Stropheodonta bipartita, Leptaena rhomboidalis, Schuchertella interstriata, Camarotoechia litchfieldensis, Wilsonia globsa, Stenocisma lamellata, Rhynchospirina formosa, Whitfieldella nucleolata, Actinopteria reticulata, Proetus pachydermatus, Calymene camerata,, Kloedenia sussexensis, Zygobeyrichia barretti.* Ostracodes are very rare in these strata; none have been observed in the new collections	6	48
Blocky calcareous shale, with thin bands of limestone. (2A11.)	7½	42
Bluish, finely crystalline, in part somewhat crinoidal, fossiliferous limestone (2A10), with 9 inches of shale (2A9) at base. In 2A10 Weller reported: *Cladopora rectilineata, Escharopora siluriana, Stropheodonta bipartita, Schuchertella interstriata, S. deckerensis, Leptaena rhomboidalis, "Dalmanella" postelegantula, Camarotoechia litchfieldensis, Stenocisma lamellata, Spirifer vanuxemi* var. *minor, Whitfieldella* sp., *Mytilarca* sp., *Pterinea "emacerata," Proetus pachydermatus.* At 31 feet above base of Decker limestone: *Limbinaria biangulata* (r)	8	34½
Ptilodictya frondosa zone: Medium-bedded, light gray, coarsely crystalline, highly crinoidal limestone in beds up to 9 inches thick, with some thin shale partings; beds near middle are reddish, hematitic; the hematite in part forms coatings on oolites, in part extends into the pores of and tends to replace crinoid fragments and perhaps other shell material. (2A8.) Weller reported: *Favosites* sp., *Cladopora rectilineata, Cyphotrypa corrugata, Vermipora* sp., *Ptilodictya frondosa, Lichenalia* sp., *Stropheodonta bipartita, Leptaena rhomboidalis, Schuchertella deckerensis, Chonetes jerseyensis, "Orthis" flabellites, "Dalmanella" postelegantula, Rhipidomella preoblata, Gypidula circularis, Stenocisma deckerensis, Camarotoechia litchfieldensis, Atrypa reticularis, Spirifer* sp., *Calymene camerata.* The 4-inch frond-like zoaria of *Ptilodictya frondosa* are conspicuous in some layers of this unit. The zone contains the highest observed occurrences of *Chonetes jerseyensis.* Ostracodes are rare; a few specimens of *Dibolbina* sp. and *Dizygopleura* sp. were found in material from these strata, but are not satisfactory for identification	2½	26½
Thin-bedded shale, with thin bands of fossiliferous, crystalline limestone, 5 inches, above, 8 inches crystalline limestone, below. (2A7 and 2A6.) Weller reported: *Stropheodonta bipartita, Chonetes jerseyensis, Camarotoechia litchfieldensis, Bythocypris nearpassi.*		

	Thickness in feet Bed	Total
Beds 2A7 to 2A3 were included in the *Chonetes jerseyensis* zone by Weller; however, he also reported the species in 2A8	1½	24
Fissile, calcareous shale with some thin bands of limestone. (2A5.) No fossils observed	6½	22½
Thick-bedded, light gray, crystalline, somewhat crinoidal limestone, with some thin, irregular shaly laminae. (2A4.) Fossils numerous, but less perfectly preserved than in the subjacent bed. Weller reported: *Favosites* sp., *Cyphotrypa corrugata*, *Lichenalia* sp., *Stropheodonta bipartita*, *Schuchertella deckerensis*, *Chonetes jerseyensis*, "*Dalmanella*" *postelegantula*, *Stenocisma deckerensis*, *Camarotoechia litchfieldensis*, *Atrypa reticularis*, "*Spirifer*" cf. *modestus* ("*Reticularia bicostata*"), *Cyrtina magnaplicata*, *Platyceras* sp.	14	16
Crystalline, highly crinoidal, sparingly arenaceous limestone. (2A3.) In collected material, the profuse crinoid plates tend to be partly replaced by limonite. The grains of quartz sand form less than 5 per cent of the rock; they are well rounded and commonly measure 0.5 to 1 mm. in diameter. Weller reported: *Zaphrentis* sp., *Cyphotrypa corrugata*, *Pholidops ovata*, *Stropheodonta bipartita*, *Schuchertella deckerensis*, *Chonetes jerseyensis*, "*Dalmanella*" *postelegantula*, *Stenocisma deckerensis*, *Camarotoechia litchfieldensis*, *Atrypa reticularis*, "*Spirifer*" cf. *modestus* ("*Reticularia bicostata*"), *Edmondia? deckerensis*, *Pterinea* sp., *Ptychopteria? subquadrata*, *Mytilarca obliqua*, *Straparollus* sp., *Loxonema* sp., *Orthoceras* sp., *Goniophora* sp., *Proetus? depressus*, "*Dalmanites*" *aspinosa*. New collections contain *Chonetes jerseyensis* (c), *C. jerseyensis* var. *nondivergens* (c), and a few poor Ostracoda, including *Dibolbina* sp. (r), *Bonneprimites breviformis* (r), *Dizgopleura* sp. (r), *Limbinaria?* sp. (r)	2	2
Thickness of Decker limestone		52
Bossardville limestone		
Dark blue to black, dense laminated limestone, weathering light bluish-gray; the laminae commonly are about $\frac{1}{16}$–$\frac{1}{2}$ inch in thickness interspersed with a few layers reaching 3 inches. *Leperditia* sp. (c) about 2 feet below top		12
Concealed		—
Thickness exposed uppermost Bossardville limestone		12

Dalton Nearpass farm, New Jersey.—Lower Devonian Oriskany and Helderberg beds, and the Upper Silurian Manlius limestone are relatively well exposed from the summit to the eastern foot of Wallpack Ridge on the farm of Dalton Nearpass in Sussex County, New Jersey, 2½ miles south of Port Jervis, New York, at about 74° 42.2′ west longitude, 41° 20.4–20.2′ north latitude in the western part of the Port Jervis quadragle. The lane leading from the Dalton Nearpass house to small quarries in the Manlius near the foot of the ridge is shown on the April, 1908, edition of the Port Jervis sheet. The Rondout limestone and upper part of the Decker limestone are incompletely exposed.

The stratigraphic succession and thicknesses of the Coeymans and Manlius are closely similar to those at the William Nearpass quarries a short half-mile to the southwest, and will not be detailed.

Ostracode faunules were collected as follows:

Lower Devonian

Coeymans limestone

Thlipsuropsis digitata (r) in slab from upper part of the formation.

Late Silurian

Manlius limestone

In ostracode-rich layers in lower half-foot of the Manlius: Cup coral (r), *Howellella vanuxemi* (r), gastropod undetermined (r), *Herrmannina altoides* (c), *Pseudobeyrichia perornata* (r), *Kloedenia crassipunctata* (r), *K. aparchoides* (r), *Lophokloedenia manliensis* (a), *Myomphalus dorsinodosus* (r), *Saccarchites* (?) sp. (r), *Kloedenella bipustulata* (r-c). This is the *Lophokloe denia manliensis* fauna.

Decker limestone

Loose, ostracode-bearing slabs of two types were discovered in a small pit just south of the Dalton Nearpass farm lane at the foot of the rise to Wallpack Ridge. The

position of the pit is about 20 to 25 feet stratigraphically below the summit of the Decker limestone, and it appeared likely that the loose slabs had been dug from the pit.

Slabs of type 1 consist of reddish crystalline, crinoidal limestone, and contain *Strophedonta bipartita* (c), *Stenocisma deckerensis* (r), *Limbinaria biangulata* (c), *Thlipsuropsis longisulcata* (r).

EXPLANATION OF PLATE 103

FIG. *1*—*Leperditia elongata* Weller. The holotype right valve, ×3, showing the elongate form, the weakly defined terminal borders. New Jersey Geological Survey Coll. 6369; William Nearpass quarries, New Jersey, 4 to 10 feet above base of Rondout limestone (2A15). (p. 1050)

2,3—*Hermannina altoides* (Weller). Two of the syntype valves, a left and a right valve, ×3. The left valve especially shows the posterior border that distinguishes *H. altoides* from *H. alta*. New Jersey Geological Survey Coll. 6367; Flatbrookville, New Jersey, lower part of Decker limestone (109B). (p. 1051)

4–6—*Aechmina eupunctella* Swartz & Whitmore, n.sp. *4,5*, The syntype right valves, ×45. In *4* the dorso-median spine is broken at its base, in *5* the tip of the spine is missing. Both specimens show the pit and adjacent node antero-ventral to the base of the spine, as well as the fine surface puncta. *6*, A left valve, ×50, the dorso-median spine broken. The peculiar punctate pustules occurring in a band paralleling the free margins have not been observed in other specimens. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1054)

7,8—*Richina zygalis* Swartz & Whitmore, n. sp. The syntype left and right valves, ×47, showing the distinct yoke-ridge joining the dorsal nodes. In *7*, the conical point of the posterior node is preserved, the fine puncta of the shell surface are clearly shown and the pit of the median sulcus is visible. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1058)

9,10—*Limbinaria paucipunctata* Swartz & Whitmore, n. gen., n. sp. Right and ventral views of holotype female shell, ×30, showing incompletely the posteriorly expanded dimorphic flange of each valve, the pit antero-dorsal to the center of the valve, the shallow, scattered surface pits. William Nearpass quarries, New Jersey, 3 feet below top of Decker limestone and 1 foot above coralline bed. (p. 1057)

11–14—*Kloedenia aparchoides* Swartz & Whitmore, n. sp. *11–13*, The syntype valves, ×20. *11,12*, Two male right valves, showing the obscure kloedenid lobation, broad submarginal border, and extremes of prominence of the posterior cardinal angle. *13*, A female left valve; the rounded, raised spot at the ventral end of the median sulcus evidently reflects the adductor scar. *14*, A small male right valve, ×20. *11–13* from quarry beside lane ascending eastern side of Trilobite Mountain, 1.2 miles northeast of Tristate, Orange County, New York, Manlius limestone 40 feet below lowest exposed beds of Coeymans limestone; *14* from quarries near southeast foot of Wallpack Ridge, on Dalton Nearpass farm, New Jersey, basal 2 feet of Manlius limestone. (p. 1067)

15–17—*Myomphalus dorsinodosus* Swartz & Whitmore, n. gen., n. sp. *15,16*, Views of syntypes, ×25. *15*, A male left valve; the two subdorsal nodes are well preserved; in this valve there is an oblique furrow above the more anterior node; the submarginal border is weakly defined, there are obscure, scattered granules on the anterior slope. *16*, An exceptionally large female right valve; the weakly defined, ventral dimorphic pouch is relatively long. Antero-ventral to the broken section of the surface is a well-defined adductor spot. *17*, A smaller female right valve, ×25, with shorter dimorphic pouch, well defined adductor spot. *15,16*, from quarries near southeast foot of Wallpack Ridge, on Dalton Nearpass farm, New Jersey, basal 2 feet of Manlius limestone. *17* from quarry beside lane ascending eastern slope of Trilobite mountain, 1.2 miles northeast of Tristate, Orange County, New York; Manlius limestone 40 feet below lowest exposed Coeymans limestone. (p. 1074)

18,19—*Saccarchites saccularis* Swartz & Whitmore, n. gen., n. sp. The syntypes, ×20. *18*, A male right valve showing the aparchitid suppression of lobation. The submedian adductor spot and surface puncta are well preserved. There is a very faint depressed line above the muscle spot and an obscure suggestion of a vestige of a median lobe anterior to the depressed line. *19*, A female left valve with large but poorly defined anteroventral dimorphic pouch, well preserved adductor spot, faint surface puncta. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1080)

20—*Phlyctiscapha?* sp. A male left valve, ×20, showing the inequality of the ends, and oblique ventral margin. The greater portion of the specimen is weathered light gray, leaving a darker band that parallels the free margins and is incorrectly suggestive of a submarginal furrow. William Nearpass quarries, New Jersey, 7 to 9 feet below top of Manlius limestone. (p. 1081)

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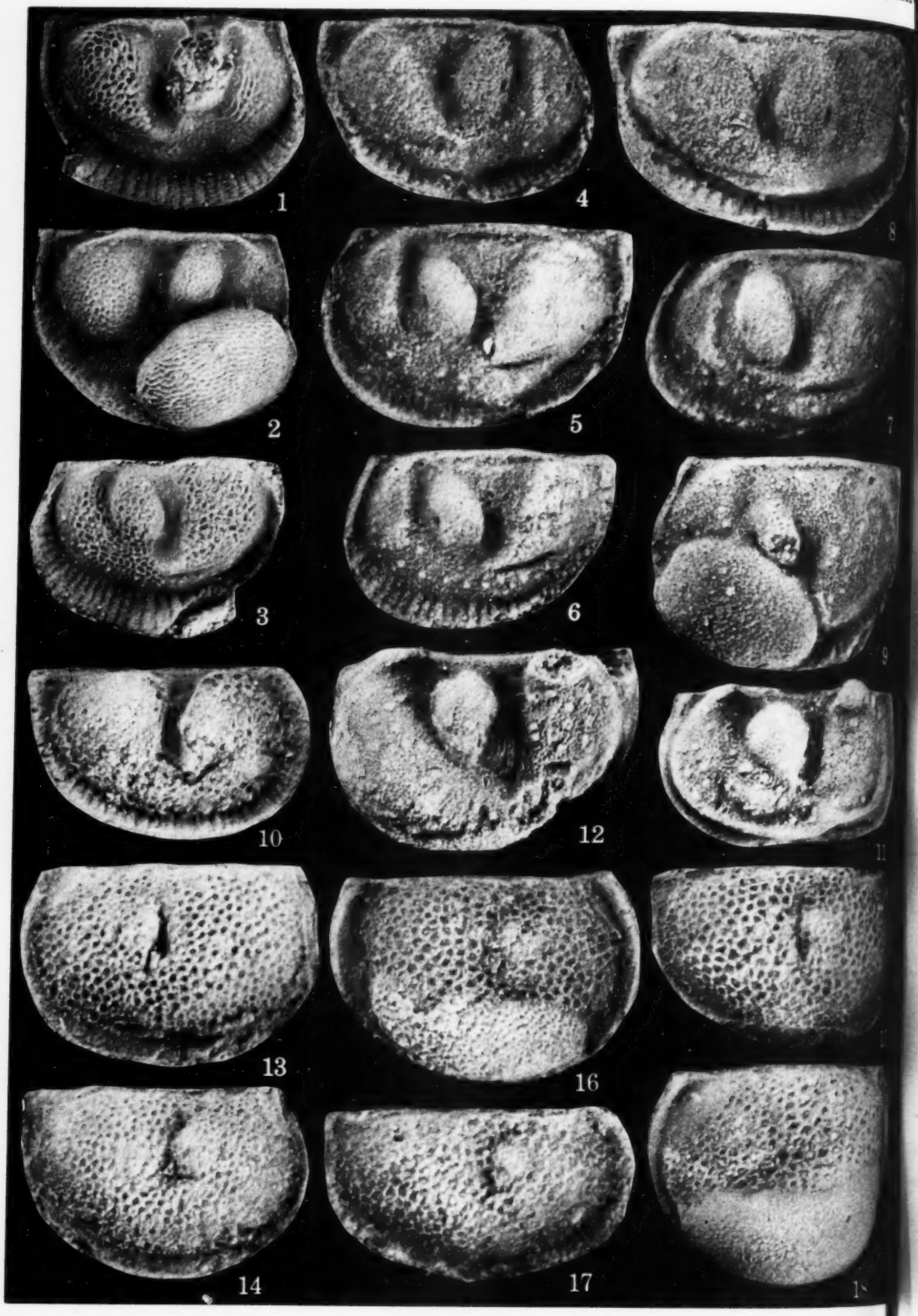
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Slabs of type 2 are gray, finely crystalline, and contain *Leperditia scalaris* (a) without other fossils.

The fauna, lithology, and stratigraphic position of the slabs of type 1 suggest a position at or slightly above the top of the *Ptilodictya frondosa* beds of the William Nearpass section; the *L. scalaris* slabs presumably come from about the same horizon although the species is not known at the William Nearpass quarries.

East slope of Trilobite Mountain, New York.—Trilobite Mountain is a hill 300 to 400 feet high, extending for 2 miles northeast of Tristate village near Port Jervis, Orange County, New York, in the west-central part of the Port Jervis quadrangle. Geologically, the hill is a continuation of Wallpack Ridge southwest of Tristate. The stratigraphy, structure, and faunas of the hill were described by Shimer in 1905; the name Trilobite Mountain comes from the profusion of *Corycephalus* ("*Dalmanites*") *dentatus* in thin layers in the Lower Devonian Port Jervis limestone.

Ostracode-rich layers were found in the Manlius limestone at a small quarry alongside the road on the eastern slope of the hill, 1.2 miles northeast of Tristate at about 78° 39.7′ west longitude, 41° 21.8′ north latitude. The section at the quarry is as follows:

Lower Devonian
Helderberg group
Coeymans limestone

Thick-bedded gray, crystalline crinoidal limestone containing the characteristic *Gypidula coeymanensis* fauna.....20 feet

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EXPLANATION OF PLATE 104

FIG. *1-3*—*Velibeyrichia reticulosaccula* Swartz & Whitmore, n. sp. Views of syntypes ×35. *1*, A male right valve showing the furrow of the post-ventral slope, the indentation of the frill. *2*, A female right valve showing the reticulose ornament of the dimorphic pouch, the crest adjoining the hinge, the lack of post-ventral indentation of the frill. *3*, A male left valve, the cardinal angles imperfect. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1059)

4-9—*Velibeyrichia paucigranulosa* Swartz & Whitmore, n. sp. Views of syntypes, ×48. *4–7*, A male right valve, and three male left valves, showing small differences in shape and size, but persistence of the sparse granules, the furrow of the post-ventral slope, the sharp summit at the posterior margin of the anterior lobe, the shallow furrow defining the low crest that parallels part of the hinge, the swelling at the dorsal end of the median sulcus. *8*, A large male right valve. In *8* the more minute set of surface granules can be seen. *9*, A female left valve. William Nearpass quarries, New Jersey, 2 feet below top of Decker limestone. (p. 1060)

10—*Diboldina macrosulcata* Swartz & Whitmore, n. sp. The holotype, a male right valve, ×35, showing the strong median sulcus; some of the surface pits are visible, though most of them are clogged with matrix. William Nearpass quarries, New Jersey, 2 feet below top of Decker limestone. (p. 1061)

11,12—*Pseudobeyrichia perornata* Swartz & Whitmore, n. gen., n. sp. *11*, The holotype male left valve, ×46, showing the dorsal nodes of the terminal lobes, the granules surmounting the minutely punctulose surface, the short ridge anteroventral to the median lobe, and the submarginal ridge that may be a vestige of the velibeyrichiid type of frill. William Nearpass quarries, Wallpack Ridge, New Jersey, 3 feet below top of Manlius limestone. *12*, A female left valve. The striate ventral part of the median sulcus may reflect the adductor scar. Quarries near southeastern foot of Wallpack ridge, near lane of Dalton Nearpass farm, New Jersey, north of William Nearpass quarries; basal foot of Manlius limestone. (p. 1062)

13-17—*Bolbiprimitia limbata* Swartz & Whitmore, n. sp. The syntypes, about ×47. *13*, A male left valve showing the broad marginal flange and narrow, short median sulcus. Anterior margin imperfect. *14,15*, Two male right valves, the second relatively elongate. *16*, A female right valve, showing the finely punctate, medioventral dimorphic pouch which, in conjunction with the posterior lobe, has a cornucopia-like appearance. William Nearpass quarries, New Jersey, 2 feet above base of Manlius limestone. *17*, A male right valve, ×45, decidedly more than normally elongate, perhaps due to distortion. William Nearpass quarries, New Jersey, 7 to 9 feet below top of Manlius limestone. (p. 1082)

18—*Bolbiprimitia teresaccula* Swartz & Whitmore, n. sp. The holotype female left valve, ×45, showing the smooth-surfaced dimorphic pouch, and reduction of the median sulcus to a small pit. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1082)

Late Silurian

Manlius limestone

Concealed; may include at top 5 or 10 feet of Coeymans limestone.....38 feet

Medium-bedded, finely crystalline, bluish-gray limestone, poorly exposed in quarry floor and along road. At 2 feet below top: *Howellella vanuxemi* (r-c), *Leperditia* sp. (r), *Kloedenia crassipunctata* (r), *K. aparchoides* (c), *Lophokloedenia manliensis* (c), *L. kummeli* (r), *Myomphalus dorsinodosus* (r), *Eukloedenella* sp. (r), *Kloedenella bipustulata* (r).....5 feet

Concealed.

The ostracodes found in the Manlius beds in this quarry represent the *Lophokloedenia manliensis* subzone, characteristic of the lower part of the Manlius at the William Nearpass section 3½ miles to the southwest.

	Thickness Feet
Lower Devonian	
Helderberg group	
Alsen limestone	
Cherty siliceous limestone. *Spirifer concinnus* fauna. Port Ewen beds may be represented in upper part	40–45
Becraft limestone	
Crystalline, crinoidal limestone; some shale interlayers in lower part. *Spirifer concinnus, Aspidocrinus* fauna	60
New Scotland shaly limestone	
Fossiliferous, argillaceous limestone; *Eospirifer macropleurus* fauna	120
Kalkberg limestone	
Dark, finely crystalline, impure limestone, with seams of black chert. *Bilobites varicus, Eospirifer macropleurus, Gypidula coeymanensis* fauna	35
Coeymans limestone	
Crystalline, crinoidal, sparingly siliceous limestone. *Gypidula coeymanensis* fauna	15
Thickness of Helderberg group	275
Late Silurian	
Manlius limestone	
Dark blue, finely crystalline to dense, in part laminated limestone. In part the "ribbon" beds have a peculiar columnar jointing due to superposed mudcracks. There are several stromatoporoid beds. *Howellella vanuxemi, Tentaculites gyracanthus* fauna. Slabs collected by F. M. Swartz at a horizon not less than 2 nor more than 5 feet below top of Manlius contain: crinoidal plates (c), *Stropheodonta varistriata* (c), *Howellella vanuxemi* (c), *Trematospira?* sp. (r), *Centronella* cf. *C. biplicata* (r), *Actinopteria reticulata* var. (r). *Aechmina eupunctella* (r), *Richina zygalis* (r), *Parabolbina cuneospinosa* (c), *Velibeyrichia reticulosaccula* (c), *Kloedenia duplicipunctata* (c), *K. crassipunctata* (c), *Lophokloedenia eufimbriata* (c), *Mesomphalus striatellus* (c), *Bolbiprimitia terresaccula* (r), *Saccarchites saccularis* (c), *Phlyctiscapha?* sp. (c), *Eukloedenella* cf. *E. manliensis* (r), *Kloedenella bipustulata* (c–a), *Thlipsuropsis diploglyptulis* (r), *Parahealdia* sp. (r), *Cavellina* sp. (r), *Bythocypris* sp. (c). Abundance of *Kloedenia crassipunctata* and *K. duplicipunctata* in association with *Kloedenella bipustulata* suggests the middle to upper part of the Manlius of the Nearpass quarries, but the full Austin's Glen assemblage has not been duplicated in the Nearpass section	50
Rondout limestone	
Impure limestone, the lower part arenaceous	6–8
Thickness of Late Silurian Manlius and Rondout beds	56–58
(Unconformity)	
Middle Ordovician	
Normanskill shale and sandstone	

Austin's Glen, New York.—During a visit to Austin's Glen, near Catskill, New York, in 1929 under the guidance of G. H. Chadwick, F. M. Swartz collected slabs from the upper part of the Manlius limestone that have proven to have an especially rich suite of ostracodes, corresponding in part to assemblages found in the upper portion of the Manlius limestone at the William Nearpass quarries in New Jersey.

Austin's Glen is a small gorge cut by Catskill Creek between hills capped by Lower Devonian sediments. It is in the north-central part of the Catskill quadrangle, 2½ miles northwest of Catskill, Greene County, New York, at about 73° 53¾′ west longitude, 42° 14½′ north latitude.

The Helderbergian-Late Silurian section found in the gorge is given below, on the basis of Chadwick's (1944) description. The ostracodes listed in the upper part of the Manlius were obtained from the slabs collected by Swartz in 1929.

Family Leperditiidae Jones
  Subfamily Leperditiinae Swartz
    Genus *Leperditia* Rouault
      Leperditia elongata Weller
        Rondout limestone, New Jersey
    Genus *Herrmannina* Kegel
      Herrmannina altoides (Weller)
        Decker limestone, New Jersey
Family Leperditellidae Ulrich & Bassler
  Subfamily Conchoprimitiinae Henningsmoen
    Genus *Bonneprimites* Swartz & Whitmore, n. gen.
      Bonneprimites (?) breviformis Swartz & Whitmore, n. sp.
        Decker limestone, New Jersey
Family Aechminidae (Boucek)
  Genus *Aechmina* Jones & Holl
    Aechmina eupunctella Swartz & Whitmore, n. sp.
      Manlius limestone, New York
Family Primitiopsidae Swartz
  Genus *Limbinaria* Swartz, n. gen.
    Limbinaria multipunctata Swartz n. sp.,
      Tonoloway limestone, Virginia and Tennessee
    Limbinaria paucipunctata Swartz & Whitmore, n. sp.
      Decker limestone, New Jersey
    Limbinaria biangulata Swartz & Whitmore, n. sp.
      Decker limestone, New Jersey
Family Drepanellidae (Ulrich & Bassler)
  Genus *Richina* Coryell & Malkin
    Richina zygalis Swartz & Whitmore, n. sp.
      Manlius limestone, New York
Family Hollinidae Swartz
  Genus *Parabolbina* Swartz

LIST OF SPECIES

The ostracodes described in the present paper are named in the following list, which also gives their respective horizons and localities of occurrence. Description of *Limbinaria multipunctata* Swartz, n. gen., n. sp., of the Tonoloway limestone of Virginia and Tennessee, is introduced in this report to provide a basis for discussion of species of the genus that occur in New Jersey. A description of the brachiopod, *Chonetes jerseyensis* var. *nondivergens* Swartz, n. var., is given in a brief appendix at the end of the systematic descriptions of the Ostracoda.

In a previous paper on Leperditiidae, Swartz (1949) described and illustrated specimens of the following species, obtained from the Nearpass quarries area: *Leperditia scalaris* Jones, Decker limestone; *L. altiscalaris* Swartz, Rondout limestone; *Herrmannina welleri* Swartz, Rondout limestone.

The species here described are as follows:

Parabolbina cuneospinosa Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey

Family Beyrichiidae Ulrich

Genus *Velibeyrichia* Henningsmoen

Velibeyrichia reticulosaccula Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey

Velibeyrichia paucigranulosa Swartz & Whitmore, n. sp.
Decker limestone, New Jersey

Genus *Dibolbina* Ulrich and Bassler

Dibolbina macrosulcata Swartz & Whitmore, n. sp.
Decker limestone, New Jersey

Genus *Pseudobeyrichia* Swartz & Whitmore, n. gen.

Pseudobeyrichia perornata Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey

Family Zygobolbidae Ulrich & Bassler

Subfamily Kloedeninae Ulrich & Bassler

Genus *Kloedenia* Jones & Holl

Kloedenia deckerensis (Weller)
Decker limestone, New Jersey

Kloedenia sussexensis (Weller)
Decker limestone, New Jersey

Kloedenia duplicipunctata Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey

Kloedenia crassipunctata Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey

Kloedenia montaguensis (Weller)
Manlius limestone, New Jersey

Kloedenia montaguensis var. *smocki* (Weller)
Manlius limestone, New Jersey

Kloedenia aparchoides Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey

Genus *Lophokloedenia* Swartz & Whitmore, n. gen.

Lophokloedenia manliensis (Weller)
Manlius limestone, New Jersey and New York

Lophokloedenia kummeli (Weller)
Manlius limestone, New Jersey and New York

Lophokloedenia eufimbriata Swartz & Whitmore, n. sp.
Manlius limestone, New York

Genus *Zygobeyrichia* Ulrich

Zygobeyrichia barretti (Weller)
Decker limestone, New Jersey

Zygobeyrichia nearpassi (Weller)
Decker limestone, New Jersey

Genus *Myomphalus* Swartz & Whitmore, n. gen.

Myomphalus dorsinodosus Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey and New York

Genus *Welleriopsis* Swartz & Whitmore, n. gen.

Welleriopsis diplocystulis Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey

Welleriopsis jerseyensis (Weller)
Decker limestone, New Jersey

Welleriopsis jerseyensis var. *microreticulis* Swartz & Whitmore, n. var.
Manlius limestone, New Jersey

Genus *Mesomphalus* Ulrich & Bassler

Mesomphalus rhomboidalis Swartz & Whitmore n. sp.
Decker limestone, New Jersey
Mesomphalus striatellus Swartz & Whitmore, n. sp.
Manlius limestone, New York; variant in Coeymans limestone, New Jersey
Genus *Saccarchites* Swartz & Whitmore, n. gen.
Saccarchites saccularis Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey
Genus *Phlyctiscapha* Kesling
Phlyctiscapha? sp.
Manlius limestone, New York and New Jersey
Genus *Bolbiprimitia* Kay
Bolbiprimitia limbata Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey
Bolbiprimitia teresaccula Swartz & Whitmore, n. sp.
Manlius limestone, New York
Family Kloedenellidae Ulrich & Bassler
Genus *Eukloedenella* Ulrich & Bassler
Eukloedenella cicatrix Swartz & Whitmore, n. sp.
Decker limestone, New Jersey
Eukloedenella manliensis Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey
Genus *Kloedenella* Ulrich & Bassler
Kloedenella bipustulata Swartz & Whitmore, n. sp.
Manlius limestone, New York and New Jersey
Kloedenella parvisulcata Swartz & Whitmore, n. sp.
Decker limestone, New Jersey
Genus *Dizygopleura* Ulrich & Bassler
Dizygopleura angustisulcata Swartz & Whitmore, n. sp.
Decker limestone, New Jersey
Dizygopleura cf. *D. clarkei* (Jones)
Decker limestone, New Jersey
Family Thlipsuridae Ulrich
Genus *Thlipsuropsis* Swartz & Whitmore, n. g.
Thlipsuropsis diploglyptulis Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey
Thlipsuropsis longisulcata Swartz & Whitmore, n. sp.
Decker limestone, New Jersey
Thlipsuropsis digitata Swartz & Whitmore, n. sp.
Coeymans limestone, New Jersey
Family Healdiidae Harlton
Genus *Parahealdia* Coryell & Cuskley
Parahealdia? convexoris Swartz & Whitmore, n. sp.
Manlius limestone, New Jersey

GENERAL ZONAL VALUES OF THE DECKER-MANLIUS OSTRACODA

The Ostracoda here described from the Decker, Rondout and Manlius limestones are numerous and diversified, are well characterized by distinctive features of shape, ornament or dimorphism, and generally appear to be restricted in stratigraphic range. They have important zonal possibilities that are summarized in Table 1, which also serves to indicate relationships to zones based on other fossil groups. Their occurrences at the William Nearpass quarries are illustrated in further detail by the bar graphs of Text-fig. 1, and similar graphs are given for non-ostracodes in Text-fig. 2.

The ostracodes and non-ostracodes of each of the successive zones of Table 1 will be considered, in order to review their significance for correlation and to help lay a basis for inferences about their paleoecologic relationships.

TABLE 1. ZONAL OCCURRENCES OF OSTRACODE AND NON-OSTRACODE SPECIES AT THE WILLIAM NEARPASS QUARRIES, NEW JERSEY

Manlius limestone

Kloedenella bipustulata, Kloedenia crassipunctata zone

In upper half: *Kloedenia montaguensis, Welleriopsis diplocystulis* subzone, with *Kloedenia crassipunctata* more common than at lower levels.

In middle beds: *Parabolbina cuneospinosa, Velibeyrichia reticulosaccula, Parahealdia? convexoris* are represented by rare examples; more data are needed concerning their subzonal values.

In lower beds: *Lophokloedenia manliensis* subzone, with *Myomphalus dorsinodosus.*

Howellella vanuxemi, Tentaculites gyracanthus zone

In upper half: *Stropheodonta varistriata, Centronella? biplicata.*

Rondout limestone

Herrmannina welleri and *Leperditia altiscalaris.*

Fossils other than Leperditiidae and some Kloedenellidae are very rare, except for *Hyattidina? lamellosa* in one thin bed.

Decker limestone

Stenocisma lamellata zone

In upper beds: *Limbinaria paucipunctata, Velibeyrichia paucigranulosa, Kloedenia deckerensis, Zygobeyrichia nearpassi, Welleriopsis jerseyensis, Eukloedenella cicatrix* subzone.

In middle beds: ostracodes rare, although Weller reported *Zygobeyrichia barretti.*

In lower beds, and perhaps in upper part of *Chonetes jerseyensis* zone: occurrences of *Limbinaria biangulata, Leperditia scalaris.*

Calymene camerata occurs in upper and middle parts, and also in uppermost beds of *Chonetes jerseyensis* zone.

In middle beds: coralline subzone with occurrences of *Cyathophyllum inequalis, Diphyphyllum integumentum, Halysites* cf. *H. catenularia. Cladopora rectilineata* occurs here and in upper part of *Chonetes jerseyensis* zone. *Schuchertella interstriata* occurs in middle and lower parts of *Stenocisma lamellata* zone.

Chonetes jerseyensis zone

Near base: *Bonneprimites? breviformis.* Identifiable ostracodes not observed in higher beds at William Nearpass quarries, though loose slabs from Dalton Nearpass farm that may have come from uppermost *Chonetes jerseyensis* beds, contain *Limbinaria biangulata* and *Thlipsuropsis longisulcata.*

In uppermost beds: *Ptilodictya frondosa* subzone with occurrence of *Gypidula circularis.*

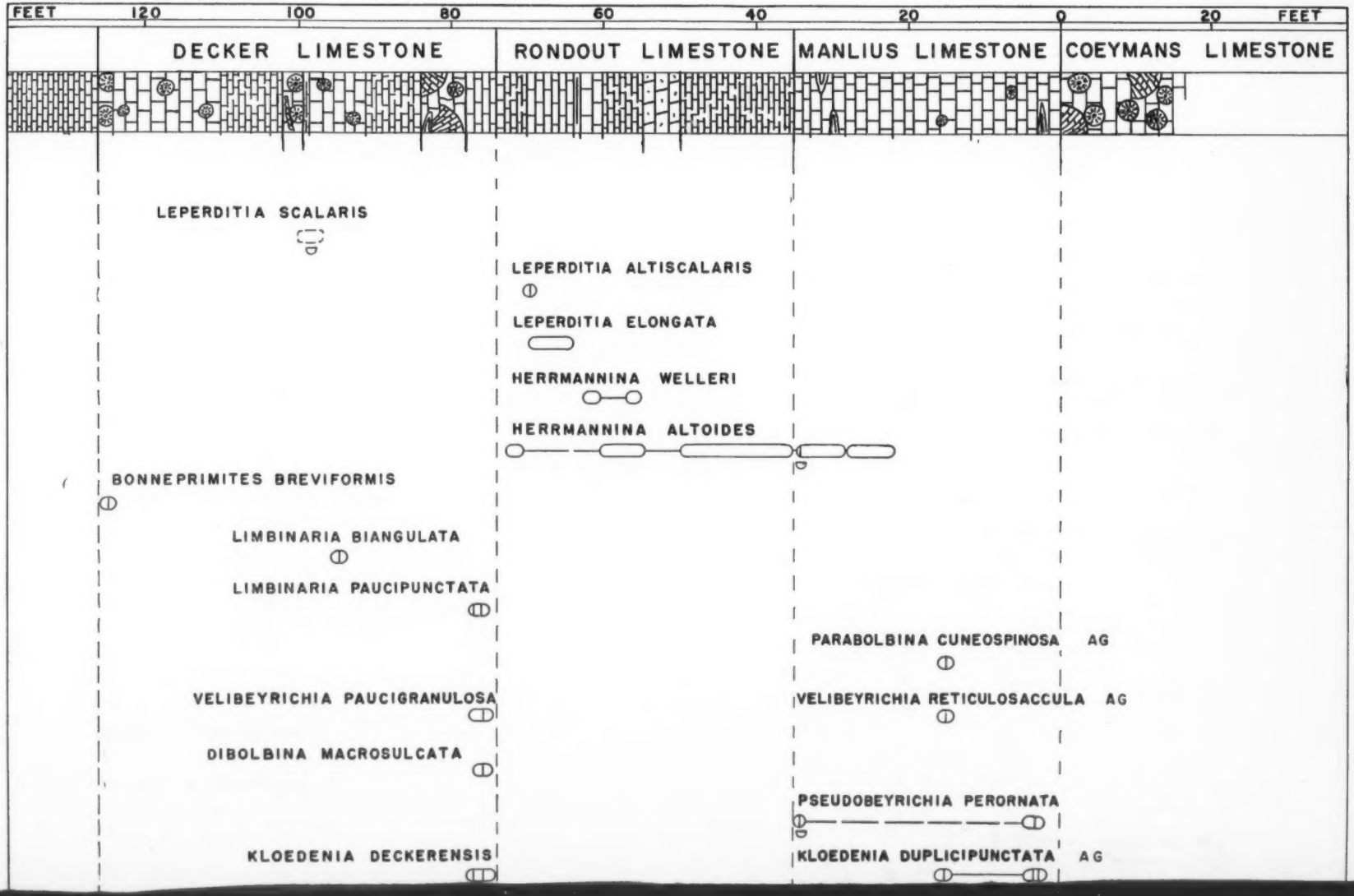
Throughout *Chonetes jerseyensis* zone: *Cyphotrypa corrugata, Stenocisma deckerensis;* throughout zone and occurring in basal part of *Stenocisma lamellata* zone: *Stropheodonta bipartita, Schuchertella deckerensis;* in lower half of zone: "*Spirifer*" cf. *modestus.*

FAUNAS OF THE *Chonetes jerseyensis* AND *Stenocisma lamellata* ZONES OF THE DECKER LIMESTONE

The strikingly ornamented *Chonetes jerseyensis,* that Weller discovered in the lower 27 feet of the Decker limestone, disappears in higher Decker beds that contain *Stenocisma lamellata* of the Cobleskill limestone of New York. This and associated faunal changes led Weller to distinguish the *Chonetes jerseyensis* zone of the lower Decker from the *Stenocisma lamellata* zone of the upper part.

Weller obtained a large fauna from the *Chonetes jerseyensis* beds at the Nearpass quarries. His identified species include one coral, two bryozoans, fourteen brachiopods, three pelecypods, three trilobites and one ostracode. Material listed only on a generic basis adds two more corals, one bryozoan, three gastropods and one cephalopod. New collections have not added appreciably to the known non-ostracode fauna of the zone.

The *Chonetes jerseyensis* fauna has proven invaluable in correlation of Upper Silurian sediments in the middle Appalachians. *Chonetes jerseyensis* itself is distinctively ornamented by the peculiar anteriorward curvature of its lateral costellae and by angulation of the post-lateral costellae from the cardinal margin. It has been found with such Decker associates as *Cyphotrypa cor-*


FEET
120
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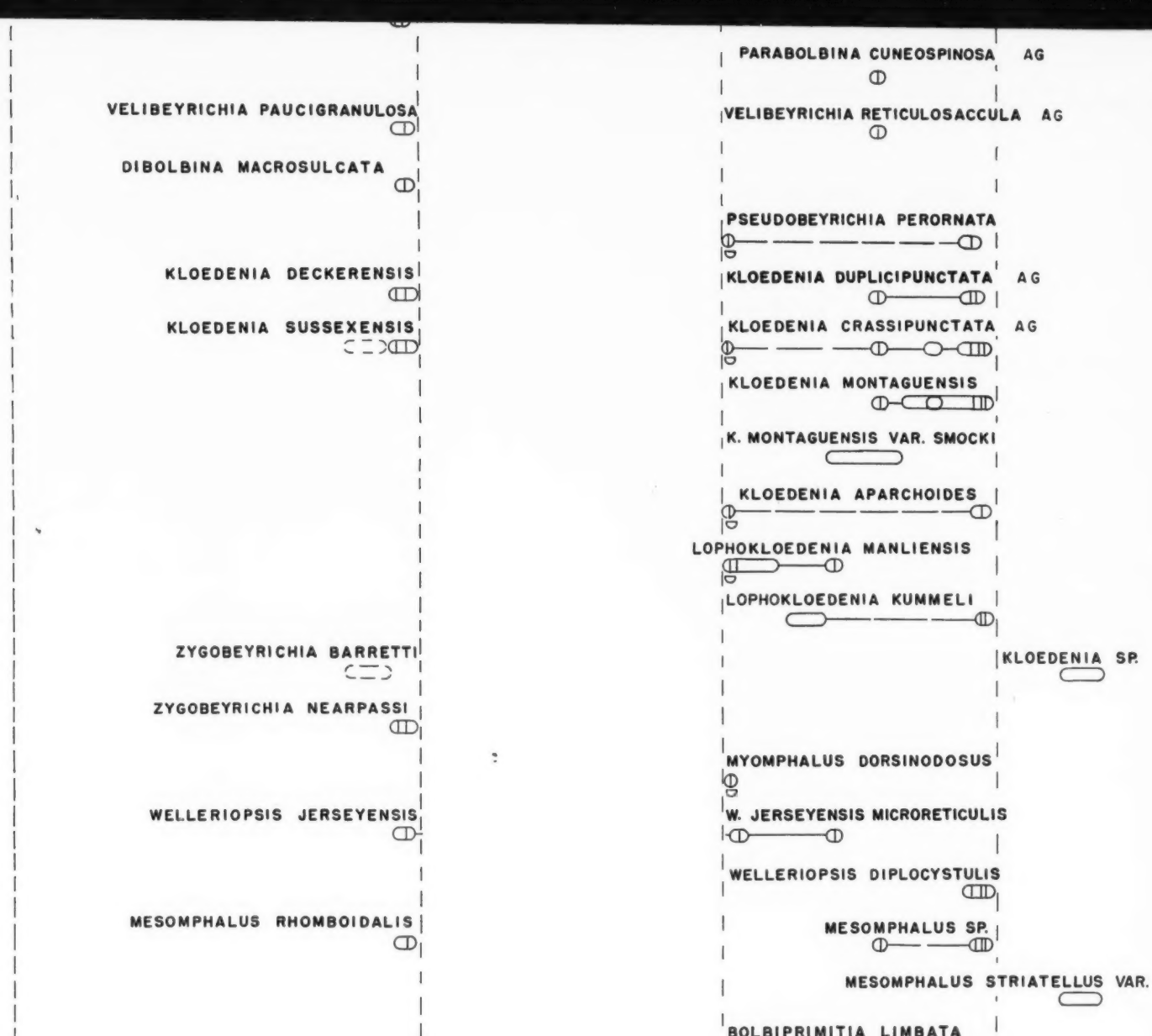
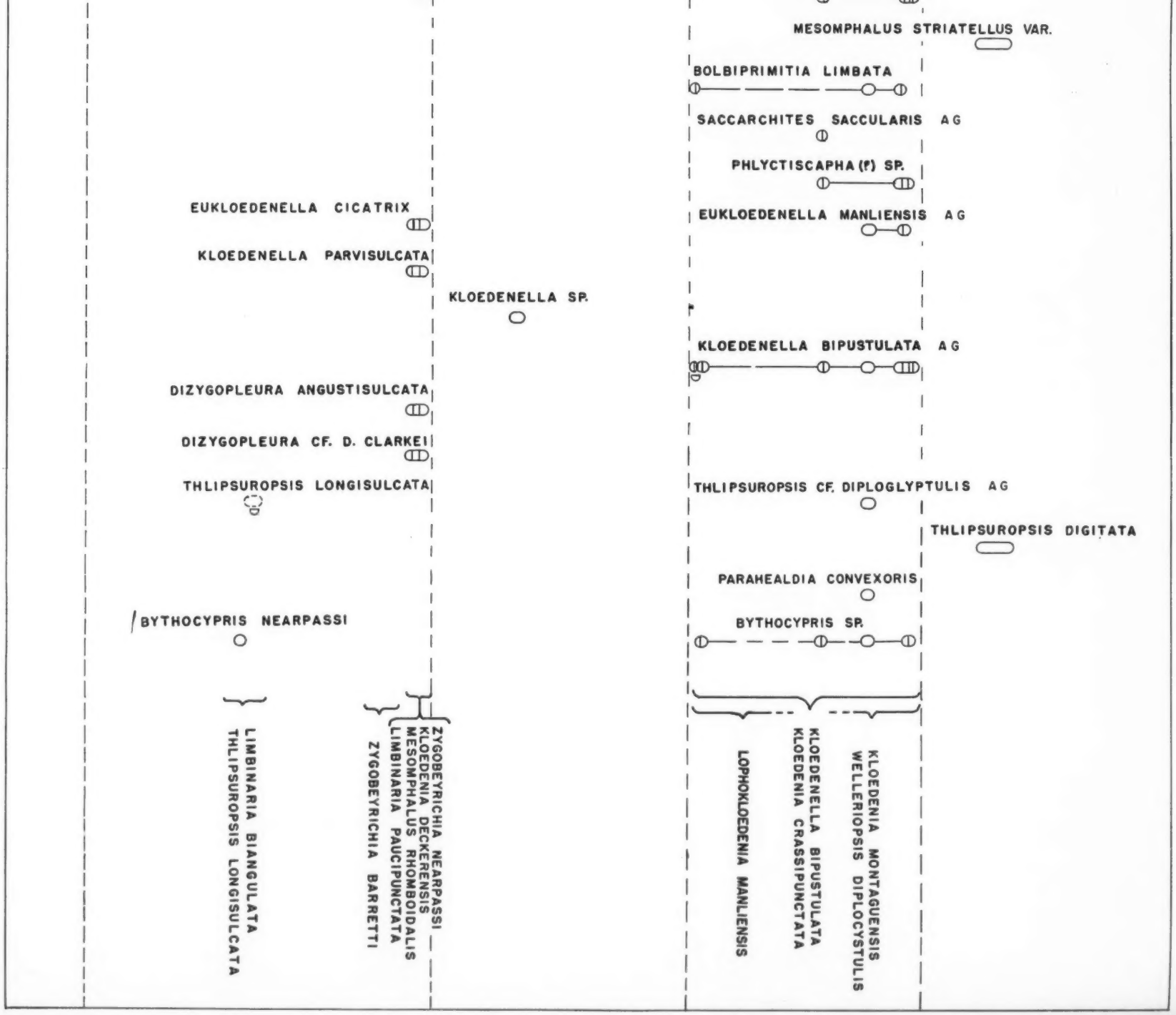
DECKER LIMESTONE
RONDOUT LIMESTONE
MANLIUS LIMESTONE
COEYMANS LIMESTONE
LEPERDITIA SCALARIS
LEPERDITIA ALTISCALARIS
LEPERDITIA ELONGATA
HERRMANNINA WELLERI
HERRMANNINA ALTOIDES
BONNEPRIMITES BREVIFORMIS
LIMBINARIA BIANGULATA
LIMBINARIA PAUCIPUNCTATA
PARABOLBINA CUNEOSPINOSA AG
VELIBEYRICHIA PAUCIGRANULOSA
VELIBEYRICHIA RETICULOSACCULA AG
DIBOLBINA MACROSULCATA
PSEUDOBEYRICHIA PERORNATA
KLOEDENIA DECKERENSIS
KLOEDENIA DUPLICIPUNCTATA AG


VELIBEYRICHIA PAUCIGRANULOSA
DIBOLBINA MACROSULCATA
KLOEDENIA DECKERENSIS
KLOEDENIA SUSSEXENSIS
ZYGOBEYRICHIA BARRETTI
ZYGOBEYRICHIA NEARPASSI
WELLERIOPSIS JERSEYENSIS
MESOMPHALUS RHOMBOIDALIS
PARABOLBINA CUNEOSPINOSA AG
VELIBEYRICHIA RETICULOSACCULA AG
PSEUDOBEYRICHIA PERORNATA
KLOEDENIA DUPLICIPUNCTATA AG
KLOEDENIA CRASSIPUNCTATA AG
KLOEDENIA MONTAGUENSIS
K. MONTAGUENSIS VAR. SMOCKI
KLOEDENIA APARCHOIDES
LOPHOKLOEDENIA MANLIENSIS
LOPHOKLOEDENIA KUMMELI
KLOEDENIA SP.
MYOMPHALUS DORSINODOSUS
W. JERSEYENSIS MICRORETICULIS
WELLERIOPSIS DIPLOCYSTULIS
MESOMPHALUS SP.
MESOMPHALUS STRIATELLUS VAR.



TEXT-FIG. *1*—Ranges of ostracode species in the William Nearpass quarries section, New Jersey. Occurrences are also included from the basal *Manlius* and middle Decker of the Dalton Nearpass farm section, and are denoted by the letter "D" placed to the right of the respective graphs at the proper horizons. The letters "AG" following names of several species of the Manlius limestone, indicate that these species also occur in the uppermost beds of the Manlius limestone at Austin's Glen, New York.

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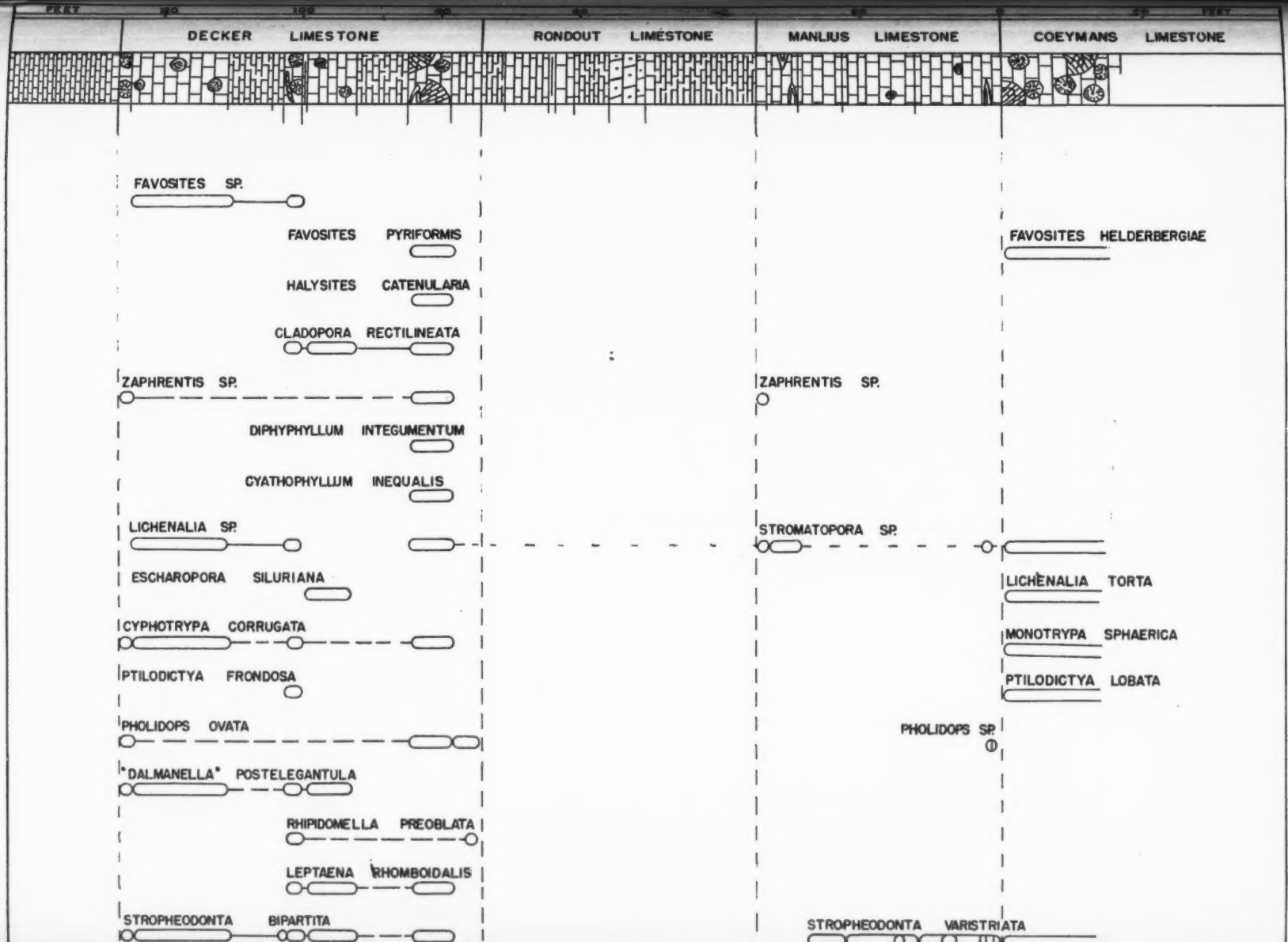
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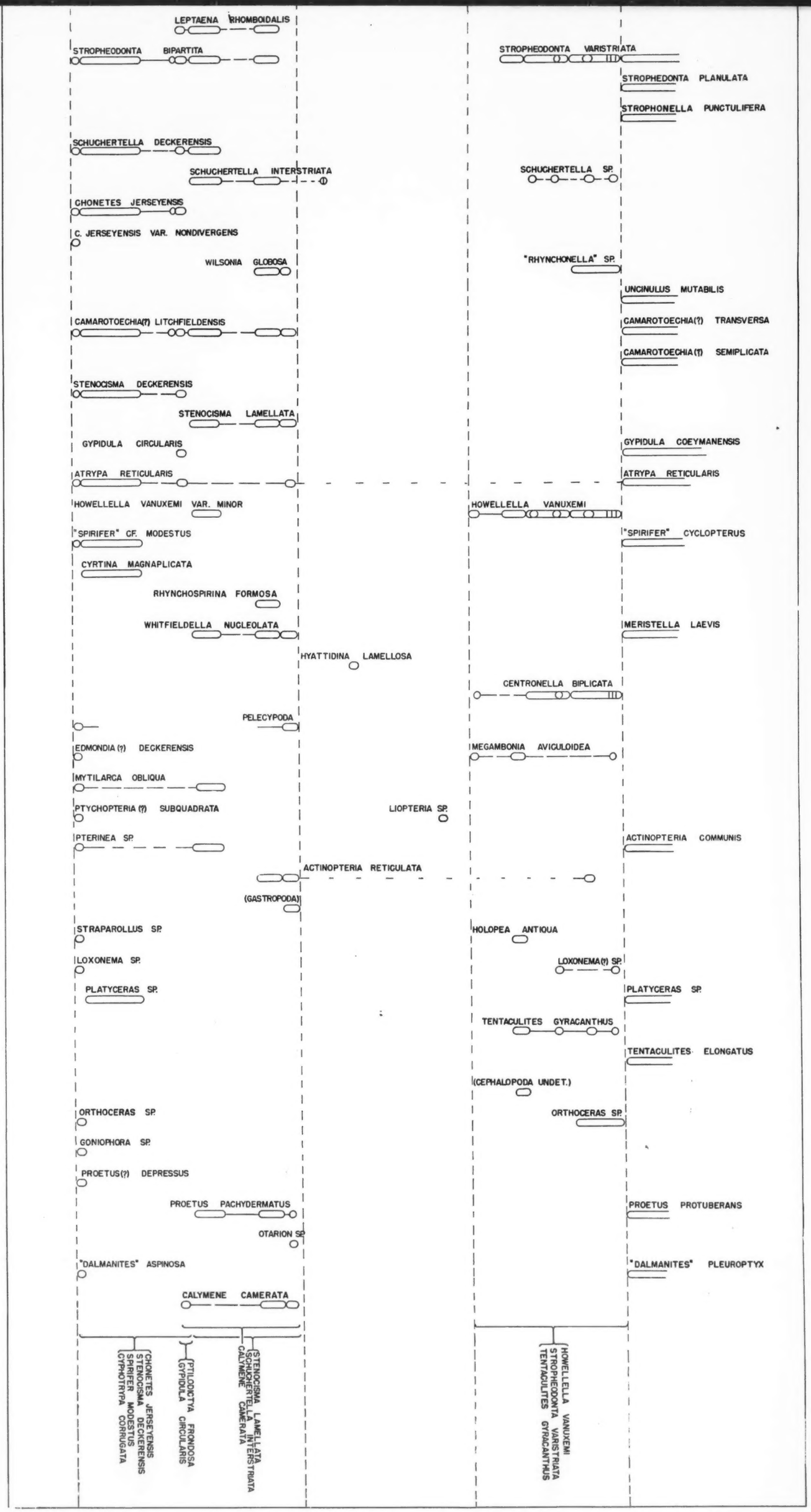
DECKER LIMESTONE
RONDOUT LIMESTONE
MANLIUS LIMESTONE
COEYMANS LIMESTONE
FAVOSITES SP.
FAVOSITES PYRIFORMIS
HALYSITES CATENULARIA
CLADOPORA RECTILINEATA
ZAPHRENTIS SP.
DIPHYPHYLLUM INTEGUMENTUM
CYATHOPHYLLUM INEQUALIS
LICHENALIA SP.
ESCHAROPORA SILURIANA
CYPHOTRYPA CORRUGATA
PTILODICTYA FRONDOSA
PHOLIDOPS OVATA
"DALMANELLA" POSTELEGANTULA
RHIPIDOMELLA PREOBLATA
LEPTAENA RHOMBOIDALIS
STROPHEODONTA BIPARTITA
ZAPHRENTIS SP.
STROMATOPORA SP.
PHOLIDOPS SP. (?)
STROPHEODONTA VARISTRIATA
FAVOSITES HELDERBERGIAE
LICHENALIA TORTA
MONOTRYPA SPHAERICA
PTILODICTYA LOBATA



TEXT-FIG. 2—Ranges of coral, Bryozoa, brachiopod, mollusk and trilobite species in the William Nearpass quarries section, New Jersey.

rugata, *Schuchertella deckerensis* and *Stenocisma deckerensis* in lower Decker beds in eastern Pennsylvania as well as in the lower half of the Keyser limestone in central Pennsylvania, western Maryland, northeastern West Virginia and northwestern and westcentral Virginia. "*Spirifer*" cf. "*S.*" *modestus* of the Decker beds is very close to if not identical with "*S.*" *modestus* that is persistent in lower Keyser beds.

Zoaria of the bryozoan, *Ptilodictya frondosa*, are conspicious in a thin subzone at the top of the *Chonetes jerseyensis* beds at the Nearpass quarries. The species has not been reported elsewhere except at one nearby locality. *Gypidula circularis* of the *P. frondosa* beds is represented by a single, poor specimen so that its possible relationship to the abundant *G. prognostica* of the middle Keyser remains uncertain.

The fauna of the *Stenocisma lamellata* zone of the upper Decker is comparable in abundance and diversity to that of the underlying *Chonetes jerseyensis* zone. Corals and ostracodes are more numerous, though they reach their respective maxima in differing strata. The identified species include five corals, one stromatoporoid, two bryozoa, 11 brachiopods, two pelecypods, two trilobites and 14 ostracodes.

Species of the Cobleskill limestone of New York are more numerous in the *Stenocisma lamellata* zone of the Decker limestone than in the *Chonetes jerseyensis* beds. In addition to *Stropheodonta bipartita* and *Camarotoechia litchfieldensis* which range throughout the Decker formation, and *Cladopora rectilineata* and *Calymene camerata* which appear in the *Ptilodictya frondosa* beds but are more abundant in the *Stenocisma lamellata* zone, the Cobleskill species include *Stenocisma lamellata* itself together with *Cyathophyllum inequalis*, *Halysites* cf. *H. catenularia*, *Schuchertella interstriata* and *Whitfieldella nucleolata*.

Marked faunal changes occur within the 25-foot succession of the *Stenocisma lamellata* beds of the Nearpass quarries. In the lower 15 feet brachiopods are common, including *S. lamellata*, *Schuchertella interstriata* and *S. deckerensis*. The coral *Cladopora rectilineata* is not abundant. There are some bryozoans and pelecypods. Ostracodes are rare although *Limbinaria biangulata* gives zonal promise because of its distinctive ornament. The next higher 6 feet of limestone constitute a coralline bed, and contain a profusion of heads and fragments of *Cladopora rectilineata*, *Favosites pyriformis*, *Halysites* cf. *H. catenularis*, *Diphyphyllum integumentum* and *Cyathophyllum inequalis*. The Cobleskill brachiopods, *Schuchertella interstriata*, *Stenocisma lamellata* and *Whitfieldella nucleolata* are common, as is the Cobleskill trilobite, *Calymene camerata*. Ostracodes are very rare; none were observed in the present study, although Weller reported *Kloedenia sussexensis* and *Zygobeyrichia barretti*. In the highest 4 feet of the zone, corals again are rare, but brachiopods are common and there is sudden introduction of a profusion of strikingly ornamented ostracodes, of which *Limbinaria paucipunctata*, *Velibeyrichia paucigranulosa*, *Mesomphalus rhomboidalis*, *Kloedenia deckerensis*, *K. sussexensis*, *Zygobeyrichia nearpassi*, *Welleriopsis jerseyensis* and *Eukloedenella cicatrix* all give promise as aids for future stratigraphic correlations.

The fossil faunas thus give strong evidence of close geologic age equivalence of the Decker limestone with the lower half of the Keyser limestone of central Pennsylvania, western Maryland and the Virginias, and the fauna of the Cobleskill limestone of New York is especially well represented within the *Stenocisma lamellata* zone. In future refinements of the present correlations, however, consideration will need to be given to seeming anomalies of occurrence of a number of the species that have been used for zonal purposes. For example, *Stenocisma lamellata* is common in the Keyser limestone in the lower part of the zone of *Chonetes jerseyensis*, rather than above the range of the latter species as in the Decker limestone. A variety occurs in Maryland in the Tonoloway limestone below the Keyser, but generally has fewer ribs than typical examples from the Cobleskill of New York. *Cladopora rectilineata* and *Cyathophyllum inequalis* locally are common in the *Chonetes jerseyensis* zone of the Keyser limestone, and *Calymene camerata* reaches its maximum abundance in the Keyser in the same zone.

The differences in comparative ranges of *Chonetes jerseyensis*, *Stenocisma lamellata*

and some of their associates in the Keyser as compared to the Decker limestone, limit, in secondary degree, the refinements in age correlation that can be inferred from them. The differences must fundamentally stem from local variations in history of the environments that affected the bottom-living organisms, and their values for paleoecologic interpretations are likely to more than outweigh the minor limitations for correlation.

Further work with ostracodes with their apparently short time spans, may contribute to future analyses of the age relations of the Decker, Keyser and Cobleskill limestones. The large suite of ostracodes of the uppermost Decker beds include numerous species that should be useful in correlation. Swartz is elsewhere describing several ostracode species from the Cobleskill of New York, none of which are represented in the Decker assemblages. The presently known ostracode species of the Decker are generally not known in the Keyser limestone, except that *Zygobeyrichia barretti* reported by Weller from the upper Decker is profuse in the Keyser in the lower part of the *Chonetes jerseyensis* zone, together with *Leperditia scalaris* which was obtained loose from presumed middle Decker beds at the Dalton Nearpass farm. The occurrences of *Zygobeyrichia barretti* suggest that *Chonetes jerseyensis* may range in the Keyser limestone into beds appreciably younger than those in which it occurs in the Decker limestone in New Jersey. Further ostracode discoveries in the Decker limestone as well as in the Keyser and Cobleskill limestones may aid solution of these details of the correlations that now are good though not final approximations.

FAUNA OF THE RONDOUT LIMESTONE AT THE NEARPASS QUARRIES, NEW JERSEY

The Rondout limestone, as defined by Weller at the Nearpass quarries, consists mostly of dark, dense, in part siliceous and in part argillaceous limestones, that in general lack faunas of the brachiopod, kloedenid-beyrichiid-ostracode type which are so strikingly developed in the underlying Decker and overlying Manlius sediments. Leperditiidae are abundant in some beds, and Kloedenellidae are fairly common although identifiable material has not yet been worked up. There are some pelecypods. Brachiopods are represented by *Hyattidina? lamellosa*, common in one thin limestone bed, and by a single specimen of the Decker-Cobleskill species, *Schuchertella interstriata*. *H.? lamellosa* is not yet known at other localities.

Among the Leperditiidae, *Herrmannina welleri* is a large and comparatively quadrate form that may prove useful for correlation. *Leperditia altiscalaris* is a relatively high version of *L. scalaris* of the Decker, Akron and early Keyser beds. *L. elongata* is presently known from a single right valve, so that its specific characters are not adequately established. *L. alta* has been reported from Manlius as well as Rondout beds.

The disappearance of kloedenid-beyrichiid ostracodes at the top of the Decker limestone, and their reappearance at the base of the Manlius beds, clearly reflect environmental changes that accompanied sedimentation, and for many of the constituent species may not closely indicate biozonal limits of range. Nevertheless, the ostracodes of the upper Decker and basal Manlius differ so greatly in their specific membership, that they may still serve as the most useful available means of interpreting the regional relations of the boundaries of the Rondout with its adjoining formations.

FAUNA OF THE MANLIUS LIMESTONE AT THE NEARPASS QUARRIES, NEW JERSEY

The Manlius limestone at the William and Dalton Nearpass quarries in New Jersey, contains the brachiopods *Stropheodonta varistriata* and *Howellella vanuxemi*, and the pteropod or pteropod-like species, *Tentaculites gyracanthus*, all three of which are significant species of the type Manlius limestone of central New York. One additional brachiopod, *Centronella? biplicata*, is moderately common, and is of further interest because it is the earliest occurring terebratulid known in the Nearpass region. Other recognized non-ostracodes are rare, and do not offer much promise for detailed correlation studies. They include the brachiopods *Schuchertella* cf. *S. interstriata*, *Pholidops* sp., "*Rhynchonella*" sp.; the pelecypods *Megambonia aviculoidae* and *Actinopteria* sp.; the gastropods *Holopea antiqua* and *Loxonema* sp.; and an unidentified orthoceratoid cephalopod. There are oc-

casional bryozoans, that presumably would repay investigation. Stromatoporoids occur in several beds in the lower and upper parts of the formation. Crinoid plates are present but in general are not abundant.

Ostracodes are more abundant and diversified in the Manlius of the Nearpass area than all other studied fossils combined. There are 22 named species, two provisionally distinguished varieties, and two species identified on a generic basis only. Many of the species are well ornamented and distinctive, and are promising for zonal work.

The Manlius limestone as a whole at the Nearpass quarries, can be considered the zone of *Kloedenella bipustulata* and *Kloedenia crassipunctata*, on the basis of two ostracode species that range about from its base to its top, and that are common and readily identifiable. *Kloedenella bipustulata* has two small nodes at the summit of its posterior slope. *Kloedenia crassipunctata* is marked by sharply impressed, coarse pits. Other species that range more or less throughout the Manlius include the marginally frilled *Bolbiprimitia limbata*, and the strikingly sculptured *Pseudobeyrichia perornata* which has been found near the top of the Manlius at the William Nearpass quarries and near the base at the Dalton Nearpass farm, and that would deserve greater emphasis were it not so rare.

On the basis of species that apparently have shorter stratigraphic ranges, an upper and a lower ostracode subzone can be recognized within the *Kloedenella bipustulata-Kloedenia crassipunctata* zone of the Manlius limestone. With further work it may be possible to distinguish a third, intermediate subzone.

The lower ostracode subzone of the Manlius beds is characterized especially by *Lophokloedenia manliensis*, which is subquadrate in form, has a finely pitted surface, and bears the generically distinctive node in the dorsal part of the median sulcus. *Welleriopsis jerseyensis* var. *microreticulis* of this subzone is somewhat questionably separated from *W. jerseyensis* of the highest Decker, but is readily distinguishable from *W. diplocystulis* of middle and upper parts of the Manlius limestone. Two additional species that appear to be distinctive of the lower Manlius subzone are *Kloedenia aparchoides* and especially *Myomphalus dorsinodosus*, which have been obtained in association with *Lophokloedenia manliensis* in basal Manlius beds at the Dalton Nearpass farm and at a section on Trilobite Mountain, New York.

In the upper half of the Manlius at the Nearpass quarries, *Kloedenia montaguensis* with its inflated ventral slope, and *Welleriopsis diplocystulis* with its granulose surface and elongate dimorphic pouch, are especially distinctive. *Kloedenia duplicipunctata* is an additional significant species, related to *K. crassipunctata* which is more common here than at lower levels. *Eukloedenella manliensis* of this subzone has a simplicity of lobation that may limit its value as a zonal species.

Several species obtained with the lower occurrences of *Kloedenia montaguensis* and *Welleriopsis diplocystulis*, have not been found in the abundantly fossiliferous material collected from the upper 5 feet of the subzone, so that their ranges need further study. At 7 to 9 feet below the top of the Manlius, *Parahealdia? convexoris* is present though uncommon, and one poor specimen was found that questionably represents *Thlipsuropsis diploglyptulis*. At 15 feet below the top, there are rare valves of *Parabolbina cuneospinosa* and *Velibeyrichia reticulosaccula*. The two latter species are common to abundant, together with *Thlipsuropsis diploglyptulis*, in the highest Manlius at Austin's Glen, New York, where neither *Kloedenia montaguensis* or *Welleriopsis diplocystulis* were observed in the present study.

FAUNA NEAR TOP OF MANLIUS LIMESTONE AT AUSTIN'S GLEN, NEW YORK

The slabs collected near the top of the Manlius limestone at Austin's Glen, New York, contain the Manlius brachiopods *Stropheodonta varistriata*, *Howellella vanuxemi*, and *Centronella?* cf. *C. biplicata*. Among the many ostracodes, *Kloedenella bipustulata* and *Kloedenia crassipunctata* are abundant, giving evidence of the same major ostracode zone that is represented by the Manlius limestone of the Nearpass quarries.

The associated ostracodes include *Kloedenia duplicipunctata* and *Eukloedenella manliensis* that occur at the Nearpass quar-

ries in the upper 15 feet of the Manlius limestone, and *Parabolbina cuneospinosa* and *Velibeyrichia reticulosaccula* that are rare 15 feet below the top of the formation. These ostracodes, as well as the relative abundance of *Kloedenia crassipunctata*, all suggest relationship with middle to upper parts of the Manlius of the Nearpass area. Correlation is however complicated by absence in the Austin's Glen collections of the abundant *Kloedenia montaguensis* and *Welleriopsis diplocystulis* that appear to be especially characteristic of the upper Manlius subzone at the Nearpass quarries; and conversely the greater or less abundance at Austin's Glen of *Aechmina eupunctella*, *Richina zygalis*, *Lophokloedenia eufimbriata*, *Mesomphalus striatella* and *Bolbiprimitia teresacculus* which are as yet wanting in the Nearpass collections. Further collecting will be needed to determine whether the ostracodes from Austin's Glen belong, as is suggested by the *Parabolbina* and *Velibeyrichia*, to a middle Manlius subzone not adequately represented in the studied Nearpass collections, or whether they less possibly are indicative of a horizon younger than the highest Manlius beds of the Nearpass section.

ANIMAL COMMUNITIES AND THEIR PALEOECOLOGIC IMPLICATIONS

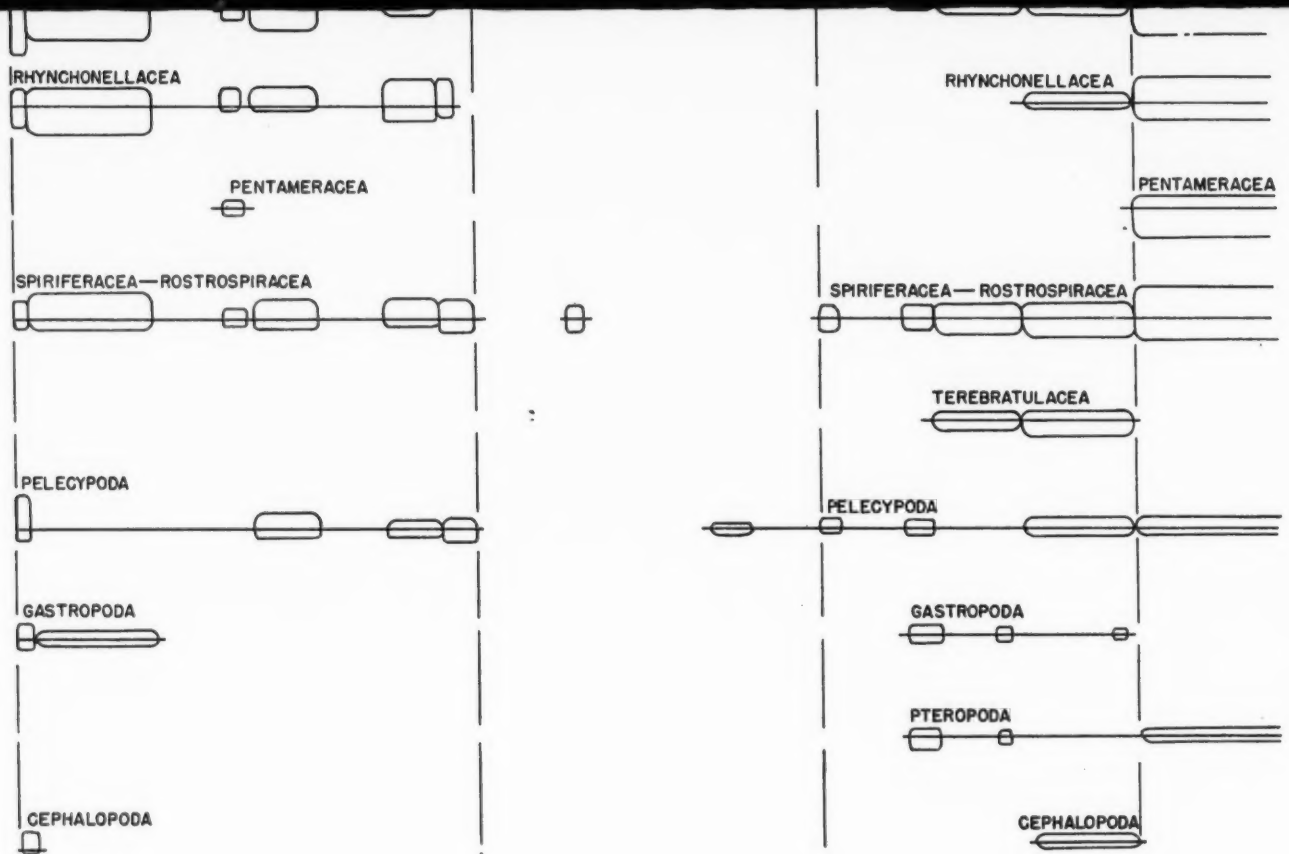
The fossils of the Decker, Rondout and Manlius limestones give evidence that during accumulation of these sediments the animal communities of the ancient sea floor in what is now the Nearpass quarries region underwent marked changes in their general nature as well as in their species membership. (See Text-fig. 3.) Observed fossils afford favorable and perhaps reasonably comprehensive records of the more common corals, brachiopods, mollusks, trilobites and ostracodes of the successive assemblages, and some knowledge of the stromatoporoids and crinoids, even though they no more than suggest the possible flourishing of associated algae, protozoans, non-shelled coelenterates, worm-like organisms, and the more fragilely carapaced crustaceans. The changes in the fossil faunas thus are significant not only for stratigraphic zonation as previously discussed, but also because of their values for paleoecologic interpretations.

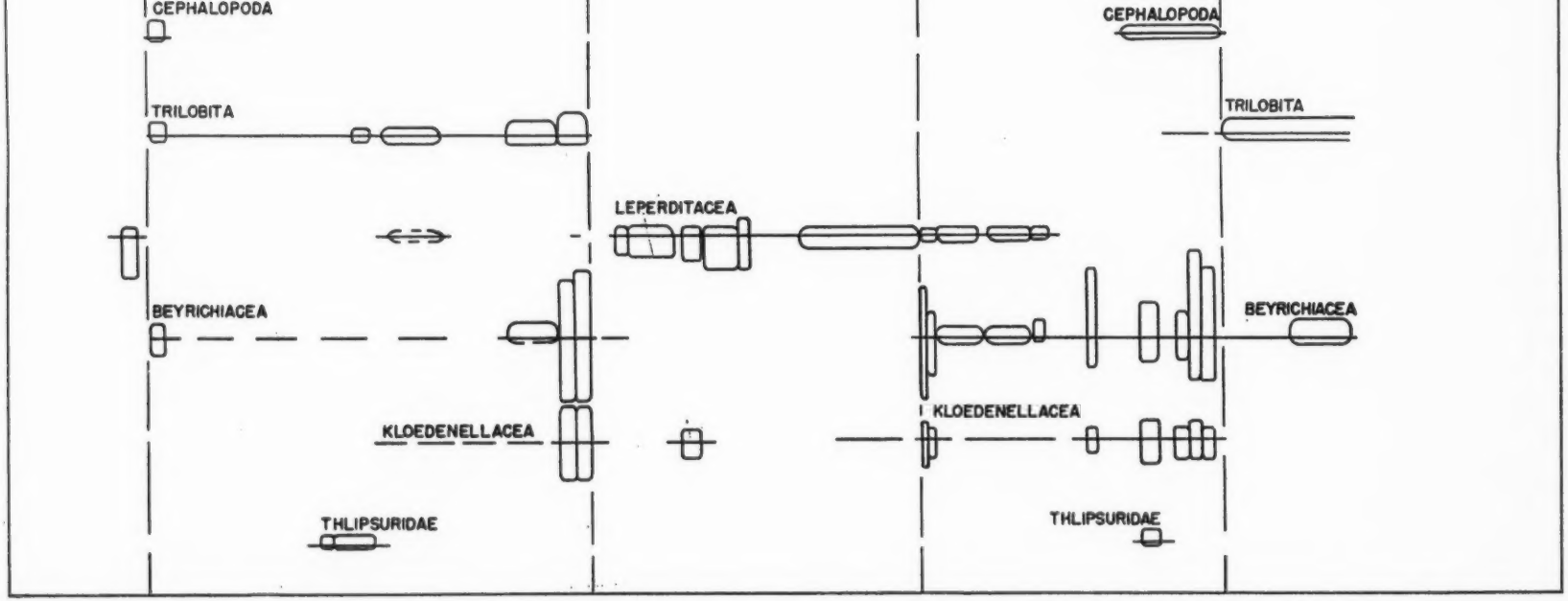
In the Decker limestone, much more than in the Rondout and Manlius, the shelly fossil faunas are both abundant and diversified. Brachiopods are numerous and include representatives of at least six of the orders of the phylum. With the associated corals, bryozoans and crinoids, they give evidence of bottom waters that were marine, well oxygenated, abounding in food, and probably warm and fairly shallow. Trilobites and ostracodes, with some pelecypods and gastropods and one cephalopod, add to the variety of the faunal assemblage.

In striking contrast to the faunas of the Decker beds, the fossils of the overlying Rondout limestone generally include few forms other than Leperditiidae, which are rare or absent in most parts of the Decker limestone, together with some Kloedenellidae. The marked faunal impoverishment may well have been occasioned by lowered salinity of the Rondout waters. As one working hypothesis, it might be imagined that the surface of Rondout sedimentation approximated sea level over extensive areas so that impaired currents of discontinuous, shallow sheets of water were unable to maintain the salinities required for abundant shelly bottom life. Limy mud flats, subject to mud-cracking such as occurs in some Rondout layers, may have been widely though discontinuously emergent.

In the Manlius limestone, above the Rondout formation, shelly fossil faunas again increase in abundance, though they do not regain the diversity found in the Decker assemblages. Stromatoporoids occur at several levels and some bryozoans are found in middle to upper beds. Crinoid plates are present, but do not form the crinoidal bands represented by several of the Decker strata. Brachiopods individually are common or even profuse in some layers, but rarely include more than two or three species. Mollusks are represented by some high-spired gastropods, and by the presumed pteropod, *Tentaculites gyracanthus*, which is moderately common at a number of horizons. Trilobites, fairly common in the Decker, have not been found in the Manlius. Leperditiidae including several Rondout species, occur in the lower third of the Manlius, although they disappear in higher beds. The non-leperditiid ostracodes form much the

FEET
120
100
80
60
40
20
0
FEET
DECKER LIMESTONE
RONDOUT LIMESTONE
MANLIUS LIMESTONE
COEYMANS LIMESTONE
STROMATOPOROIDEA
ANTHOZOA
BRYOZOA
CRINOIDEA
CRANIACEA
DALMANELLACEA
STROPHOMENACEA—PRODUCTACEA
RHYNCHONELLACEA
PENTAMERACEA


RHYNCHONELLACEA
PENTAMERACEA
SPIRIFERACEA—ROSTROSPIRACEA
PELECYPODA
GASTROPODA
CEPHALOPODA
RHYNCHONELLACEA
PENTAMERACEA
SPIRIFERACEA—ROSTROSPIRACEA
TEREBRATULACEA
PELECYPODA
GASTROPODA
PTEROPODA
CEPHALOPODA



TEXT-FIG. 3—General characters of the fossil faunas of the Decker, Rondout and Manlius limestones of the William and Dalton Nearpass quarries, New Jersey. The left half of each bar graph is indicative of the number of recognized species, including forms listed on a generic basis only; the right half of each bar graph suggests in a very qualitative way the general abundance of individuals, on the basis of observations incidental to preparatory work on the studied collections, but estimates of abundance could be greatly improved by field observations made more particularly for this purpose.

most abundant and diversified element of the studied Manlius faunas, and are distinctly more numerous than in all but the uppermost beds of the Decker limestone.

The local conditions for marine bottom life evidently were much improved during Manlius sedimentation as compared to the interval of Rondout deposition, but in some such factor or factors as water salinity, oxygenation, temperature or depth, had not reattained a balance wholly favorable to most of the groups of marine bottom dwellers that had flourished in the Decker seas, and that were to return in profusion in Coeymans time. Gentle to moderate rather than strong movement of the bottom waters is suggested by the well preserved ostracodes that occur at many levels in the Manlius. Concentrations of the fragile carapaces suggest local shifting on the floor of sedimentation, but the valves in general show little abrasion and were buried in the accumulating sediment rather than destroyed or swept to other areas.

Superimposed on the major changes in general nature of the animal communities by which the diversified shelly faunas of the Decker gave place to the impoverished groups of the Rondout and these in turn to the again-enlarged assemblages of the Manlius, were second order changes that are reflected within each of the three formations. For example, in the Decker beds, the limestones 4 to 10 feet below the upper boundary contain numerous small coralline heads and fragments in which six coral species have been distinguished. Bryozoans and brachiopods are fairly common, and mollusks and trilobites are represented. Crinoid fragments occur though they are not profuse. Ostracodes, however, are very rare; a few specimens were reported by Weller but none have been observed in material collected for the present study. In contrast, the next overlying, highest 4 feet of the Decker limestone abound in ostracodes, but corals are rare although brachiopods are common. The fossils of both of these limestone bodies represent marine bottom dwellers, but the changes in assemblage suggest appreciable ecologic modifications. It is possible that the shift in faunal character marks a significant stage in the transition from the more favorable Decker environments to the conditions that caused impoverishment of the Rondout assemblages. On the other hand, it is by no means unlikely that communities differing in such fashion coexisted within relatively short distances on the Decker sea floor, in more exposed areas of active coral growth as compared to locally protected niches more favorable for both ostracode life and preservation.

In the middle and lower parts of the Decker limestone, brachiopods are common at many levels and generally are associated with bryozoans, trilobites and a few mollusks. Corals occur but are not numerous. Some of the beds abound in crinoid fragments. Ostracodes are not well represented. The brachiopod-bearing and crinoid-rich layers must again reflect sedimentation in shallow, well-oxygenated marine waters of near-oceanic salinities, though the depths may have been slightly greater than those in which corals flourished to form the coralline bed of the upper part of the Decker formation. Bottom currents and wave agitation probably were fairly vigorous in and near the banks of crinoid fragments, and transport may have modified local though probably not the over-all abundances of the shelly remains as compared to the living communities that they represent.

In the shaly Decker interbeds in which fossils have not been recognized (see Text-fig. 3), further study will be required to determine whether shells are as sparse as seems apparent, and if so to obtain clues as to whether their rarity reflects temporary or local paucity of shelled life, or local destruction or removal of shell material.

In the Rondout limestone, most beds appear to lack fossils other than Leperditiidae and some Kloedenellidae, and even these groups apparently are wanting in other layers. Abundance of the Leperditiidae in strata lacking brachiopods, crinoids and bryozoa such as those that abound in the Decker limestone, gives support to the view that the leperditiids flourished chiefly in environments not favorable for the majority of the diversified bottom organisms of the shallow, well-oxygenated, normally saline areas of the Middle Paleozoic seas, and perhaps that they more largely inhabited waters of appreciably lowered or heightened salinities.

In the Rondout collections, brachiopods are common only in material from one thin limestone layer about 13 feet above the base of the formation. The observed specimens from this layer represent the single species, *Hyattidina? lamellosa* (Weller). The enclosing limestone is comparatively pure. Associated fossils include *Herrmannina welleri* together with a species of *Kloedenella*. In many of the *Kloedenella* specimens the valves are joined together, and the shell interior is filled with sparry calcite. Many of the *Hyattidina* shells also have the valves conjoined. Evidently the bottom waters were locally quiet during deposition of this stratum, and there was little shifting of even the thin, 1-mm. long kloedenellid shells after death of the enclosed animals. In some of the other Rondout layers, however, there are both kloedenellid and larger leperditiid valves that are separated and generally aligned along the bedding, giving evidence of gentle to moderate movement of the bottom waters. There is thus evidence of enough water activity to suggest that the oxygen content was not sufficiently lowered to account for the very marked impoverishment of the Rondout shelly faunas, and it is more likely that the cause lies in lowered salinity.

Other than the *Hyattidina* occurrences, brachiopods have been found in the Rondout at the Nearpass quarries only at 6 feet above the base of the formation, where a single valve of *Schuchertella interstriata* was discovered. A few pelecypod valves occur in several loose slabs coming apparently from the upper 15 feet of the formation. No stromatoporoids, corals, crinoid plates, bryozoans, trilobites or beyrichiid-kloedenid ostracodes have as yet been recognized.

In the Manlius, as in the Decker and Rondout sediments, the general nature of the faunas undergoes appreciable change at successive stratigraphic levels. The beyrichiid-kloedenid and kloedenellid ostracodes are less affected than other fossil groups; their representatives are common to abundant in individual layers in lower, middle and upper parts of the formation, though they vary in number from bed to bed, perhaps in part due to drifting of their easily moved valves into local depressions on the sea floor. Leperditiids on the other hand, continue from the Rondout into the lower part of the Manlius but are rare or absent in the middle and higher parts. The concommitant increase in numbers of *Howellella vanuxemi*, *Strophedonta varistriata* and *Centronella? biplicata* gives evidence of a trend toward more normal salinity in the gradually changing Manlius waters, as does the coming in of *Tentaculites gyrancanthus*.

Striking changes thus take place in the fossil faunas of successive parts of the Decker-Rondout-Manlius limestones. Further collecting is likely to show somewhat greater continuity of occurrence through some of the beds in which no fossils were observed in the present study, but is not likely to modify significantly the basic patterns that are evidenced in the accompanying graphs. Separation of shell pieces and alignment along bedding give evidence of local drifting of material on the sea floor, and in the coralline bed of the upper Decker many shells are worn and fragmented. In general, however, even the easily moved ostracode valves are well preserved and have nearly complete margins, and so suggest that their transport was local and does not greatly affect the faunal record. The faunal changes reveal both evolution of related species that will be invaluable in regional correlation, and changes in over-all faunal nature that reflect modifications in the water environments that affected growth of the shelly bottom life, perhaps at times in a local fashion and at other times on a regional basis. Both types of change are invaluable for interpretation of the history of the organisms and of the environments and paleogeography of sedimentation.

ADDUCTOR SCARS

Rounded marks, that evidently are external reflections of adductor scars, are visible in accompanying illustrations of valves of *Myomphalus dorsinodosus*, *Saccarchites saccularis*, *Kloedenia aparchoides*, *Bonneprimites breviformis* and *Thlipsuropsis diploglyptulis*. Additional specimens with possible muscle marks are figured for *Richina zygalis*, *Velibeyrichia reticulosaccula*, *Pseudobeyrichia perornata*, *Lophokloedenia eufimbriata*, *Kloedenia montaguensis* and *K. sussexensis*. In the *Myomphalus*, the striking appearance of the mark in one of the studied specimens is given recognition by the proposed generic name.

The presumed adductor marks of the specimens of Beyrichiidae and Kloedeninae occur persistently in the lower part of the median sulcus, except that in *Saccarchites saccularis* the sulcus is no more than a faint depression above the mark. The mark also lies directly below a short median sulcus in *Bonneprimites breviformis*, which provisionally is listed with the Leperditellidae.

The location of the marks accords with Bonnema's (1934) view that the median sulcus of the primitiid-beyrichiid-kloedeninid ostracodes is associated with the position of adductor attachment.

In *Thlipsuropsis diploglyptulis* of the Thlipsuridae the adductor mark is submedian in location. It does not occur in a depression.

Muscle marks were not studied in the two specimens of *Leperditia* described in the present paper. Details have been given elsewhere (Swartz, 1949) of adductor and other scars of specimens of *Leperditia scalaris*, *L. altiscalaris* and *Herrmannina welleri*, obtained from Decker and Rondout beds of the Nearpass quarries area.

The ostracode specimens studied for the present report occur in well lithified limestones so that it is difficult to determine details of the muscle scars. Except in the previously described Leperditiidae, subordinate features have not been observed in the adductor scars, and no accessory scars have been observed in the region of the anterior sulcus, such as were reported in several European species by Hessland (1949).

ORIENTATIONS USED FOR DESCRIPTION

In accompanying descriptions, the straight-backed primitiid-beyrichiid-kloedenid-hollinid as well as the kloedenellid ostracodes are oriented so that the median lobe and anterior sulcus, where present, are anterior to the median sulcus, and so that the less prominent cardinal angle as well as the full or plenate end of the shell normally are anterior in location. The convex-backed Thlipsuridae are oriented so that supposed adductor locations are anterior to midlength, and in one species so that subterminal spines have a posteriorward tilt.

The orientation used for the straight-backed forms accords with that advocated for many years by Bonnema (1909, 1934). It was employed by Swartz (1933) in the Kloedenellidae so that dimorphic swellings discovered in numerous Silurian species of the family would be posterior in location, and subsequently was extended with much uncertainty to other groups (Swartz, 1936), even though the dimorphic structures of several families are in consequence placed near the anterior end of the shell. Evidence favoring general use of this orientation for the straight-backed families has been further strengthened by Triebel (1941), who called attention to the possibility that the second sulcus of bisulcate species may reflect location of muscle attachments that should be anterior to midlength, and the likelihood that large spines of the valve surface should have a posteriorward rather than anteriorward tilt in order to reduce snagging against obstructions.

There is much plausibility to Triebel's (1941) view that large spines of the valve wall should have a posteriorward tilt, on the basis of comparisons with the posteriorward tilt of large spines in living species and their closer fossil relatives as well as from the general supposition that trouble with snagging would be lessened. Triebel's suggestion that the second sulcus where present may reflect the locus of interior attachment of muscles such as those of the mandibles and antennae, also deserves careful consideration and investigation. Scars of secondary muscles plausibly including those of mandibles, antennae and other appendages and even of the abdomen, are extensively developed anterior to midlength in the Leperditiidae (Swartz, 1949). Hessland (1949) has illustrated one internal mold of each of five species of primitiid-beyrichiid-tetradellid ostracodes, in which there are spots at the position of the second sulcus and elsewhere in the area of the margin of the median lobe, that may reflect scars of such secondary muscles. Additional search is needed for other occurrences of such secondary muscle marks, and more highly magnified figures of the marks in Hessland's specimens would aid judgment about their significance.

In the straight-backed species described in the present paper, numerous valves give evidence of the association of the median sulcus with the place of adductor attachment, in the fashion recognized many years ago by Bonnema. The location of the median sulcus with respect to midlength does

not however afford a very satisfactory basis for either comparative or absolute orientation of the specimens: at least, it varies markedly in position with respect to midlength on the basis of orientations here employed using interrelationships of the median sulcus, median lobe, second sulcus, and less prominent cardinal angle.

The observed variation in location of median sulcus with respect to midlength appears to have considerable relation to the complexity of sulcation. In Kloedenellidae, the median sulcus is distinctly anterior to midlength as here understood in the unisulcate *Eukloedenella cicatrix*, less markedly so in the unisulcate *E. manliensis;* in the bisulcate *Kloedenella bipustulata* and *K. parvisulcata* it varies from slightly anteromedian to slightly postmedian. The median sulcus or median pit also tends to occur appreciably anterior to midlength in unisulcate members of other families, such as *Richina zygalis* of the Drepanellidae, *Aechmina eupunctella* of the Aechminidae, *Limbinaria paucipunctata* of the Primitiopsidae, *Parabolbina cuneospinosa* of the Hollinidae and *Saccarchites saccularis* and *Bolbiprimitia limbata* of the Kloedeninae. It is submedian in location in *Mesomphalus rhomboidalis* of the Kloedeninae, which is unisulcate but has an appreciably developed median lobe and a faint suggestion of a second sulcus.

Virtually all of the remaining straight-backed, non-leperditiid ostracodes described in this paper are bisulcate, and in general the median sulcus is appreciably posterior and not anterior to midlength according to the orientations here employed.

Hypotheses concerning control of the adductor position include diverse possibilities, such as the suppositions that an anterior adductor location would aid control of the valves when opened as the animal moved forward against stresses of the water medium, or that the location is controlled morphologically rather than dynamically by relative size of the cephalic as compared to thoracic and abdominal parts of the ostracode animal. According to the first supposition, the principal part of the adductor might be shifted posteriorward, provided secondary adductor strands are developed at a more anteriorward location or if antennal or mandibular muscles might in some way serve as subordinate adductors: this supposition would also provide an explanation of the second sulcus of the bisulcate forms. The parallelism in the posteriorward shift in locus of the median sulcus and presumably of the adductor in members of divergent families tends to suggest that the cause more probably was dynamic than strictly morphologic.

SYSTEMATIC PALEONTOLOY

Family LEPERDITIIDAE Jones
Subfamily LEPERDITIINAE Swartz
Genus LEPERDITIA Rouault
LEPERDITIA ELONGATA Weller
Pl. 103, fig. 1

Leperditia elongata WELLER, 1903, Geol. Survey, New Jersey, Paleont., vol. 3, p. 259, pl. 23, fig. 13.

Leperditia elongata ULRICH & BASSLER, 1923, Maryland Geol. Survey, Silurian, p. 747, pl. 36, fig. 1,2.

Shell dorsally truncate, elongate subovate, the height about six-tenths of length. Hinge margin straight for about seven-tenths of greatest length; cardinal angles distinct, subequally obtuse. Posterior margin higher and more broadly and regularly rounded than anterior margin; ventral margin convex, fuller posteriorly than anteriorly. Hinge detail not observed.

Surface of valve moderately convex; greatest convexity anterior to midlength. Narrow borders parallel the terminal margins. Eye tubercle distinct, located about one-sixth distance below dorsal margin, one-third from anterior margin. Details of muscle scars not studied. Surface seemingly without fine ornament.

Length 12 mm., height 7 mm.

Relationships.—Leperditia elongata is characterized, as its name suggests, by its relatively elongate form.

Only the holotype right valve of *L. elongata* has been definitely identified for the species. Information is needed about the form of the left valve, and especially about presence or absence of a leperditiid dorsal swelling. *L. elongata* may in fact prove to be a right valve of *Leperditia scalaris* Jones, since its form and general characters agree closely with those of right valves of *L. scalaris* figured by Swartz (1949) from loose material obtained from the Decker? limestone on the Dalton Nearpass farm, New

Jersey. Pending further information, however, the valve is here refigured using Weller's name for it.

Occurrence.—William Nearpass quarries, New Jersey, 4 to 10 feet above base of Rondout limestone.

Genus HERRMANNINA Kegel

HERRMANNINA ALTOIDES (Weller)

Pl. 103, fig. 2,3

Leperditia altoides WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 252, pl. 23, fig. 1,2.

Shell dorsally truncate, bluntly subovoid in outline, the height more than two-thirds of length in a left valve. Hinge relatively short, about six-tenths of length. Cardinal angles distinct but obtuse. Posterior margin broadly rounded; anterior margin more narrowly curved; ventral margin strongly convex, fullest behind midlength. Details of hinge and overlap not observed.

Surface moderately convex, greatest convexity anterior to midlength. A narrow border parallels posterior margin. Eye tubercle low, situated about one-fourth distance from dorsal margin, one-third distance from anterior margin.

Details of muscle scars not studied.

The figured syntype left valve measures length 7 mm., height 5 mm. The figured right valve measures length 6 mm., height 3.5 mm.

Relationships.—*Herrmannina altoides* lacks the post-dorsal swelling of the left valve that characterizes members of *Leperditia* proper.

H. altoides was distinguished by Weller (1903) from *Leperditia alta* (Conrad) Jones, 1856, because of the narrow border margining the posterior edge.

Occurrence.—Lower part of Decker limestone, Flatbrookville, New Jersey.

Family LEPERDITELLIDAE Ulrich & Bassler

Subfamily CONCHOPRIMITIINAE Henningsmoen

Genus BONNEPRIMITES Swartz & Whitmore, n.gen.

Shell elongate subovoid, truncated dorsally by straight hinge that is somewhat shorter than greatest length of shell; free edges without strong overlap; hinge in genotype bears faint longitudinal grooves and ridges that may have supported ligament and that did not necessarily interlock; surface of valve convex, not umbonate, bearing a single subvertical, dorso-submedian sulcus, lacking ridges, knobs, submarginal rim or frill, or grooves representative of margins of early-stage valve molts; dimorphism apparently wanting.

Genotype.—*Primitia bonnemai* Swartz, 1936, from Silurian beds, Island of Gotland.

Relationships.—Rediscovery by Warthin (1948) of the designation by S. A. Miller in 1889 of *Beyrichia strangulata* McCoy as the genotype of *Primitia* Jones & Holl, has required reorganization of both *Primitia* and the family Primitiidae (e.g., Henningsmoen, 1953.) *Primitia* as based on *P. strangulata* includes species that are unisulcate to weakly lobate, and that have an anteroventral frill that is converted into a pouch in the female dimorph. The non-frilled and apparently non-dimorphic "*Primitia*" *bonnemai*, and similarly "*Beyrichia*" *mundula* Jones which for many years was considered the genotype of *Primitia*, accordingly must be removed from *Primitia*. *Bonneprimites* is here proposed at least to include "*P.*" *bonnemai*.

The family relationships of *Bonneprimites* are obscure. Tentatively, the genus is listed under the subfamily Conchoprimitiinae Henningsmoen, since it agrees in general form, unisulcation and lack of submarginal rim or frill with *Conchoprimites* Hessland of this subfamily. As compared to the latter genus, it lacks grooves paralleling the free margins that presumably represent edge impressions of early-stage valve molts, and is not known to have the strong "blood-canals" that occur at least in *Conchoprimitia socialis vulgaris* Henningsmoen (1954a).

Further information is especially needed concerning the statement by Öpik (1953) that in his studies of numerous Silurian ostracodes from the drift of Germany, and the Silurian of the Island of Gotland, "every Primitia of the *mundula* group 'without any border' proved to be a male, and could be matched to corresponding forms having a posterior, open, brood-chamber-like structure. Generally speaking, *Primitia* in this sense behaves like the genus *Primitiopsis* Jones." (Öpik, 1953, p. 30.) Since the type specimens of *Bonneprimites bonnemai* came

from the Silurian of the Island of Gotland and are so suggestive of "*Primitia*" *mundula* that they had tentatively been identified under this name in the collections of J. H. Bonnema who kindly sent them to Swartz for study, reinvestigation should be undertaken to search for possible primitiopsid dimorphism. However, in view of Bonnema's extensive work with dimorphic Primitiopsidae, and the excellent preservation and apparent abundance of *Bonneprimites bonnemai* in Bonnema's collections, it will be surprising if specimens showing primitiopsid dimorphism will be found in this species.

With future discoveries of additional, interlinking species, consideration will also need to be given to possible relations of *Bonneprimities*, as well as of *Milleratia* Swartz (1936), to members of the Kloedenellidae.

In addition to *Bonneprimites bonnemai*, *Beyrichia mundula Jones* may be listed provisionally in *Bonneprimites* pending further information concerning the dimorphism discussed by Öpik, and *Bonneprimites? breviformis* Swartz & Whitmore, n. sp., likewise can be included in the genus on a tentative basis. In all of these species, the difficulty with classification reflects lack of knowledge of structures that provide favorable clarification of interrelationships.

Occurrence.—The type material for *Bonneprimites bonnemai* comes from talus of Silurian marl, in the brick quarries at

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EXPLANATION OF PLATE 105

FIG. *1–4—Mesomphalus rhomboidalis* Swartz & Whitmore, n. sp. *1,2*, The syntypes ×35. *1*, A male right valve, the anterior cardinal angle restored. The specimen shows the elongate, rhomboidal form of the species, the numerous puncta with finely granulose interspaces, and the longitudinal furrow of the post-ventral slope. *2*, A female right valve, with the distinctive mesomphalid, medioventral, elongate dimorphic pouch. William Nearpass quarries, New Jersey, 2 feet below top of Decker limestone. *3*, A male left valve, ×35, with sparse puncta. *4*, A smaller "male" left valve, ×35, preserving a medioventral flange or frill. This probably is a valve of an immature female, the ventral flange representing an undeveloped dimorphic pouch. William Nearpass quarries, New Jersey, 2 feet below top of Decker limestone. (p. 1077)

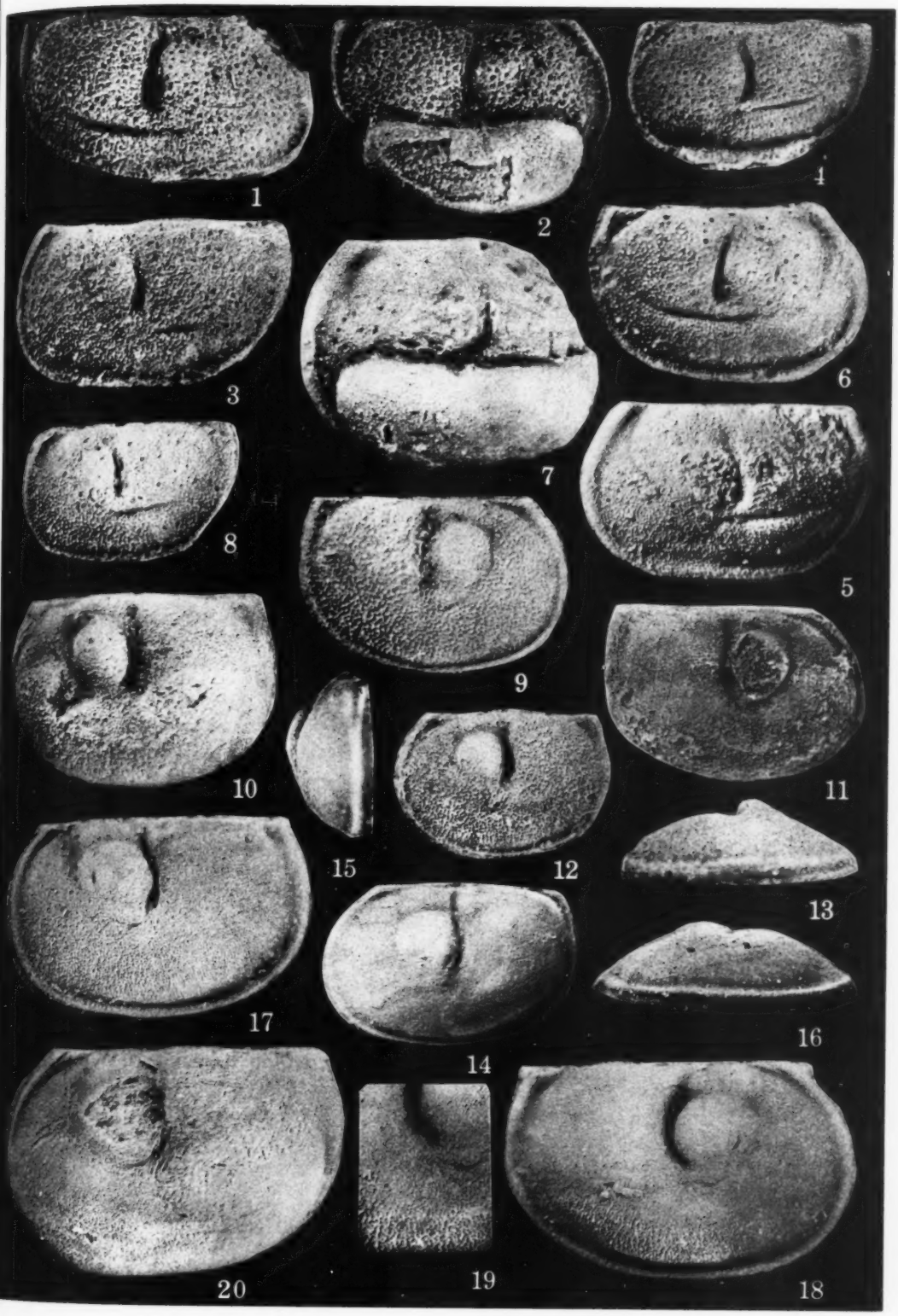
5–7—Mesomphalus striatellus Swartz & Whitmore, n. sp., *5*, A male left valve, ×35, referred to the species with some question. *6*, The holotype male right valve, ×35, showing the upcurved, faint anterior extension of the furrow of the ventral slope, the sparse puncta, the obtuse but prominent posterior cardinal angle. *7*, An associated, imperfect female left valve, ×35. *5* from William Nearpass quarries, New Jersey, 8 to 15 feet above base of Coeymans limestone; *6,7*, from Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1078)

8—Mesomphalus sp. A small male left valve, ×35, suggestive of *M. striatellus* in sparseness of puncta; however, the posterior cardinal angle is prominent and suggests *M. rhomboidalis*, and there is little trace of any anterior extension of the ventral furrow. The specimen may be an immature molt that does not completely illustrate the adult characters. William Nearpass quarries, New Jersey, 1½ feet below top of Manlius limestone. (p. 1079)

9–13—Welleriopsis diplocystulis Swartz & Whitmore, n. gen., n. sp. *9–11*, The syntypes. *9*, A male right valve, ×35, showing outline proportions, the rounded median lobe not reaching the dorsal margin, the minutely punctate-granulose ornament. *10,11*, A female left valve, ×30, and a female right valve, ×25, showing the elongate ventral dimorphic pouch of the genus, tending to be divided into two parts by the indentation associated with the median lobe. *12,13*, A male left valve, ×25, and ventral view of a male right valve, ×30. William Nearpass quarries, New Jersey, upper part of Manlius limestone; *9* is from 3 feet below top; *10,11,13* from 1½ feet below top; *12* from 2 feet below top. (p. 1075)

14–16—Welleriopsis jerseyensis (Weller). Side, anterior, and ventral views of the holotype male left valve, ×19, showing the rather large but low median lobe, its dorsal margin well below the dorsal margin of the valve. New Jersey Geological Survey Coll. 5932, from William Nearpass quarries, New Jersey, upper 4 feet of Decker limestone (2A13). (p. 1075)

17–20—Welleriopsis jerseyensis var. *microreticulis* Swartz & Whitmore, n. var. Views of the syntype valves. *17*, A male left valve, ×25. *18,19*, A male right valve, ×25, and part of surface near median sulcus, ×36, showing the curved, relatively short median sulcus, the well marked cardinal angles. The punctate-reticulate surface ornament is minute even with the enlargement given in fig. *19*. *20*, A female left valve, ×25, the median lobe imperfect. William Nearpass quarries, 2 feet above base of Manlius limestone. (p. 1076)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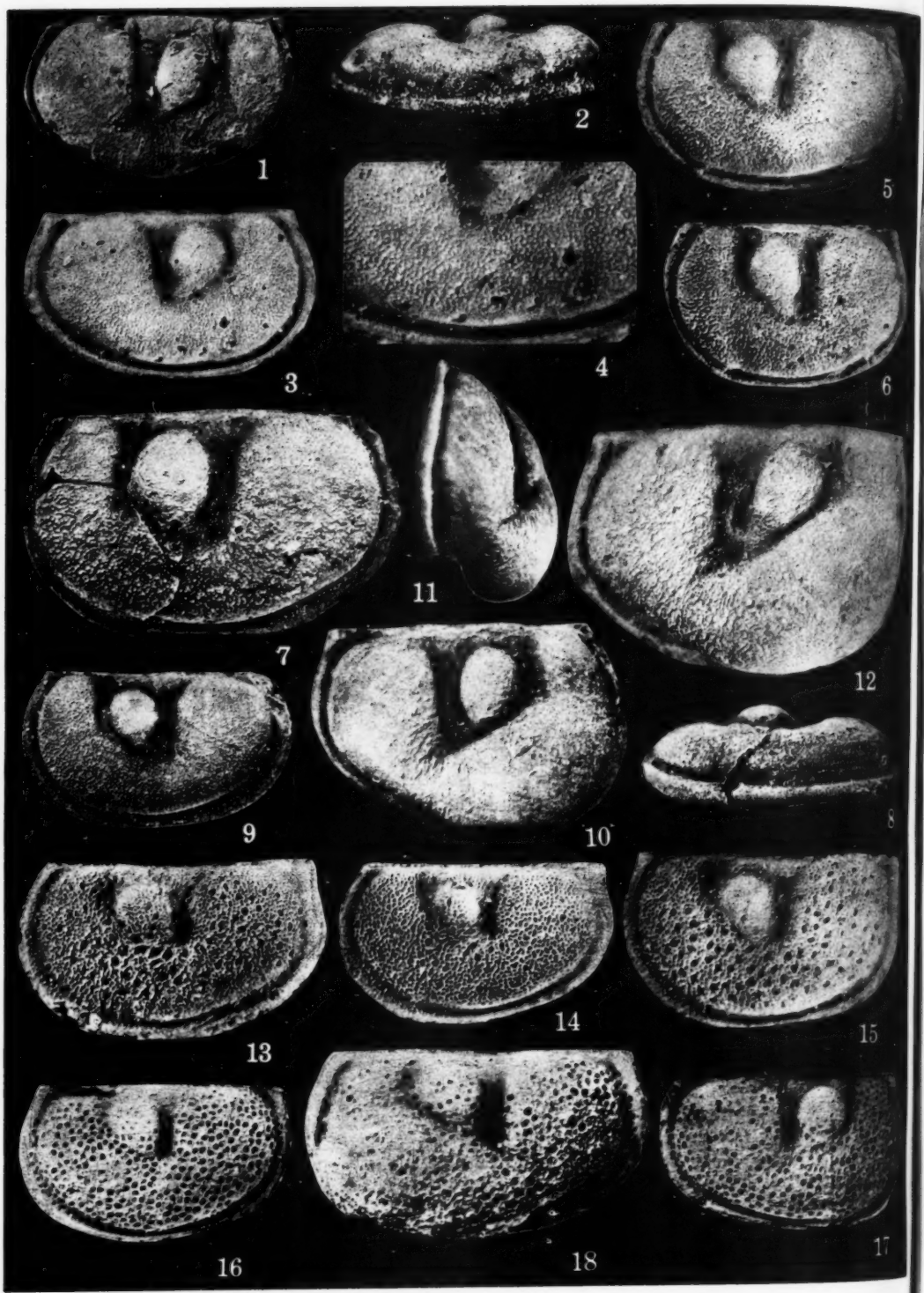
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Mulde, Island of Gotland. The type specimen of *B.? mundula*, British Museum No. I 6880, is from T. R. Jones' "No. 1 limestone" specimen from the Silurian drift, Berlin, Germany. *B.? breviformis* occurs in the basal part of the late Silurian Decker limestone, New Jersey.

BONNEPRIMITES? BREVIFORMIS Swartz & Whitmore, n.sp.
Pl. 110, fig. 20–22

Shell short, subquadrate in outline, height about four-fifths of length. Dorsal margin straight for about four-fifths of length; anterior cardinal bend rounded; posterior angle obtuse, not very prominent. Ventral margin convex in outline; terminal margins subequally rounded.

Surface of valve convex, rising steeply from posterior margin, much more gently from anterior margin, reaching greatest convexity about one-fifth distance from posterior margin. Median sulcus is located slightly posterior to midlength; the sulcus is short, reaching only about one-fourth distance from dorsal to ventral margin; it does not reach an obscure, small rounded depression at about midheight of valve, that evidently is external expression of adductor attachment. Area anterior to sulcus is very faintly swollen, forming a scarcely discernible suggestion of a median lobe. Surface of valve smooth. Dimorphism not known.

The syntype valves measure length 0.9 mm., height 0.7 to 0.75 mm.

Relationships.—Bonneprimites? breviformis differs from the genotype, *B. bonnemai*, in its much shorter form, in the postmedian location of the maximum convexity, and in the shortness and dorsal location of the median sulcus, which does not extend to the locus of the muscle spot. If additional spe-

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EXPLANATION OF PLATE 106

FIG. *1–6—Kloedenia deckerensis* (Weller). *1,2*, Side and ventral views, ×17, of holotype male right valve, showing the strongly elevated lobes. Judging from the illustrated topotype material the holotype has been somewhat deformed. New Jersey Geological Survey Coll. 7344; William Nearpass quarries, New Jersey, upper 4 feet of Decker limestone (2A13). *3,4*, A male right valve, ×20, and part of surface of same, ×35, showing the minute surface granules. *5,6*, Two male left valves, ×20, showing constancy of outline of shell, form of lobes including the obliquely directed, narrowed ventral part of the median lobe. In *6* especially, there is a faint suggestion of a zygobeyrichiid ventral extension of the anterior furrow. *3,4* from William Nearpass quarries, New Jersey, 3 feet below top of Decker limestone or 1 foot above coralline bed; *5,6* from same locality, 2 feet below top of Decker limestone. (p. 1063)

7–12—Kloedenia sussexensis (Weller). *7–9*, Views of syntype valves, *7,8*, Side and ventral views of a slightly imperfect male left valve, ×24, and ×18, respectively, showing in *7* the coarser papillae interspersed with the fine granules of the type occurring in *K. deckerensis*. *9*, A male left valve, ×17, the posterior cardinal angle imperfect. The outline of shell, character of marginal border, form of the median and other lobes, and weak zygobeyrichiid extension of the anterior furrow, show the close relationship with *K. deckerensis*. *10, 11*, Side and posterior views of female right valve, ×17; this is the specimen used by Weller (1903) as the type of *Beyrichia perinflata*. *12*, Another female right valve, ×19, the ornament of the posterior and median lobes well preserved; the mark near the ventral end of the median sulcus may reflect the adductor scar. *7–9*, New Jersey Geological Survey Coll. 7355, William Nearpass quarries, New Jersey, upper 4 feet of Decker limestone (2A12). *10, 11*, New Jersey Geological Survey Coll. 7338, same locality, horizon 2A13. *12* from same locality, 2 feet below top of Decker limestone. (p. 1064)

13–15—Kloedenia duplicipunctata Swartz & Whitmore, n. sp. *13*, The holotype, a male left valve, ×35, showing the scattered, large puncta, and smaller puncta of the interspaces. The shell resembles that of *K. sussexensis* in its outline and in proportions of its lobes. William Nearpass quarries, New Jersey, 20 feet above base of Manlius limestone. *14,15*, Two male left valves, ×35, showing variations in numbers of the coarser puncta; in *15* there is close approach to *K. crassipunctata*. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1065)

16–18—Kloedenia crassipunctata Swartz & Whitmore, n. sp. The syntypes, ×20. *16,17*, A male left valve and male right valve, showing the characteristically coarse puncta, the obliquely directed, narrowed ventral part of the median lobe. *18*, A female left valve. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p.1065)

cies with comparable dorsal location of the sulcus are discovered, their separation in a distinct genus could well be justified.

The external, rounded adductor spot of *Bonneprimites? breviformis* may aid future consideration of the relations of the species. No well defined spot of this type was observed by Swartz in the type specimens of *B. bonnemai*. The spot is suggestive of the rounded marks of some of the specimens of *Kloedenia*, *Myomphalus* and *Saccarchites* that are illustrated in the present paper.

In the Nearpass quarries collections, *Bonneprimites? breviformis* is represented by only three specimens. Larger collections are needed to provide more assurance concerning possible dimorphism. The three collected specimens agree closely with each other in dorsal profile as well as in lateral aspect.

Occurrence.—Rare in basal 2 feet of Decker limestone, William Nearpass quarries, New Jersey.

Family AECHMINIDAE Boucek
Genus AECHMINA Jones & Holl
AECHMINA EUPUNCTELLA Swartz & Whitmore, n. sp.
Pl. 103, fig. 4–6

Shell dorsally truncate, subovate in outline; hinge margin straight for about four-fifths of length; height without spine about three-fifths of length; anterior cardinal angle slightly obtuse, posterior angle more obtuse. Anterior margin higher than other, but blunter and not projecting so far beyond limits of hinge. Ventral margin moderately convex, fuller anteriorly. Hingement and overlap not observed.

Surface of valve moderately convex, surmounted by a stout, dorso-median spine, the diameter of its base about one-fourth of length of valve. One observed valve preserves a portion of spine which projects at an angle of about 30 degrees from plane of conjunction of valves and is also tilted posteriorly; length of spine and nature of its terminus remain, however, undetermined. The small, sharply depressed pit anterior to base of spine is in turn bordered anteroventrally by a well defined, small rounded knob.

Surface of valve is marked by sharply impressed, small puncta, the interspaces nearly equal to diameter of pits. Small granules tend to form a line paralleling ventral margin of valve. In one specimen, there is a belt of broad-tipped, medially pitted granules placed well within and paralleling free margins; no granules of this type are found on other two studied examples.

The larger syntype right valve measures length 0.88 mm., height 0.51 mm.

Relationships.—*Aechmina eupunctella* has the pit antero-ventral to the base of the dorso-median spine, that was considered by Ulrich & Bassler (1923) to be one of the distinguishing features of *Paraechmina*, but it lacks the marginal ridge of the characteristic members of that genus. *Aechmina bigeneris* Swartz, 1936, and *A. spinoterminata* Swartz, 1936, similarly have the pit but not the marginal ridge, and bear submarginal spines somewhat suggestive of those of the *Aechmina* genotype, *A. bovina* Jones. Warthin has listed *A. bigeneris* and *A. spinoterminata* under *Aechminaria* Coryell & Cuskley, 1934, but close relationship to the type of that genus does not appear well assured. Restudy of *Aechmina bovina* would be most helpful, to determine whether it may have some degree of development of the paraechminid pit, even though none is shown in Jones' figures.

Aechmina eupunctella lacks the submarginal spines of *A. bigeneris* and *A. spinoterminata*, and the node adjacent to the paraechminid pit is stronger. The surface puncta, and the curvature of the posterior as compared to the anterior margin may also prove distinctive.

Occurrence.—Rare 3 to 5 feet below top of Manlius limestone, Austin's Glen, New York.

Family PRIMITIOPSIDAE Swartz
Genus LIMBINARIA Swartz, n.gen.

Shell subovate, truncated dorsally by straight hinge, its length approaching total length of shell; cardinal angles prominent; right valve overlaps slightly on left along free margins. Surface of valve has a comparatively large, somewhat elevated medial area, varyingly pitted or grooved; a rounded submedian pit is well developed and presumably reflects locus of adductor attachment; in one dimorph, a more or less continuous narrow ridge or rim parallels margins of valve, dorsally as well as along other mar-

gins, and is offset farther from valve edge in vicinity of cardinal angles than elsewhere; in other dimorph, a broad, typically flat flange or frill extends along one terminal margin and adjacent portion of ventral margin, and evidently is developed from corresponding parts of submarginal ridge of non-frilled dimorph. If submedian pit, presumably representative of adductor location, is antero-median in location, then dimorphic frill occurs along posterior and post-ventral margins.

Genotype.—*Limbinaria multipunctata* Swartz, n. sp., Late Silurian Tonoloway limestone, Virginia and Tennessee.

Relationships.—At the time of discovery of the non-frilled dimorph of *Limbinaria multipunctata*, it was thought that the species belonged to the multipunctate group of thlipsurids that has been included in *Octonaria* Jones, and that the truncate margin was ventral in position. Discovery of the frill-bearing dimorph controverted both this classification and orientation, and forced consideration of relationships with non-thlipsurid families.

The type of dimorphism found in *Limbinaria*, in which the broad, thin, more or less terminal frill of one dimorph is wanting in the other dimorph, is suggestive of the dimorphism that characterizes various genera of the family Hollinidae Swartz. However, the general ornament of *Limbinaria*, with its pitted or grooved medial area, rounded submedian pit, and submarginal ridge of the non-frilled dimorph, diverges markedly from the generally sulcate-lobate, in part node-bearing ornament of the Hollinidae. The locus of the submedian pit, on the assumption that it represents the position of adductor attachment, gives some reason to believe that the frill of *Limbinaria* may occur at the end of the shell opposite that on which the frill is found in the Hollinidae, and in any event the submedian pit in *Limbinaria* occurs on the side of mid-length of the shell away from rather than toward the end bearing the frill.

The straight hinge of *Limbinaria*, the submedian pit, the surface pitting and lack of lobation, and the presence of a dimorphic expansion at the end of the shell away from the position of the median pit, all favor comparison with *Primitiopsis planifrons* Jones, the genotype of *Primitiopsis* Jones, and hence *Limbinaria* is here listed with *Primitiopsis* in the Primitiopsidae. The dimorphic frill in *Limbinaria multipunctata* differs from that of *Primitiopsis planifrons*, since in the latter species the frill or flange is confined to the end of the valve and does not extend along part of the ventral margin, and the frill is incurved distally so that the outer edge of the frill of one valve meets that of the opposing valve when the shell is closed. In *Primitiopsis dorsoplicata* Henningsmoen (1954b), however, the dimorphic frill or velum extends along most of the ventral margin and is said to be "flat." *P. dorsoplicata* is smooth surfaced, has only a weak suggestion of a short, dorso-submedian furrow, and has a strong crest paralleling the dorsal margin.

The species that currently appear to belong in *Limbinaria* are as follows:

Limbinaria multipunctata Swartz, n.sp., Late Silurian Tonoloway limestone, Virginia and Tennessee.

Limbinaria paucipunctata Swartz & Whitmore, n.sp., Late Silurian Decker limestone, New Jersey.

Limbinaria biangulata Swartz & Whitmore, n.sp., Late Silurian Decker limestone, New Jersey.

The following additional species may belong in *Limbinaria:*

Octonaria altoonensis Swartz, 1932, Late Silurian Keyser limestone, central Pennsylvania.

Octonaria? angulata Ulrich & Bassler, 1913, Late Silurian. Keyser limestone, Maryland.

Octonaria muricata Ulrich & Bassler, 1923, Late Silurian Tonoloway limestone, Maryland and Virginia.

No dimorphic frills or flanges have yet been discovered in *Limbinaria biangulata*, or in "*Octonaria*" *altoonensis*, "*O.*" *angulata* or "*O.*" *muricata*. Lack of observed frilled dimorphs is not surprising in *Limbinaria biangulata*, and *L.? altoonenesis* which are represented in available collections by only a few specimens. Swartz has obtained more than a dozen specimens of *L.? muricata*, so that lack of observed frilled dimorphs raises a somewhat greater question concerning inclusion of the species in *Limbinaria*. In both *L.? muricata* and *L.? angulata*, the medial

elevated area is longitudinally grooved rather than pitted, so that it may prove desirable to place these species in a distinct genus, even if primitiopsid dimorphism can be found in them.

Limbinaria? altoonensis, L.? angulata and *L.? muricata* have heretofore been illustrated with the truncate margin in the octonarid, ventral position. If they are proper members of *Limbinaria*, the truncate margin is the dorsal margin.

Occurrence.—The species that can now be included in *Limbinaria* have been found in Late Silurian limestones in Virginia, Tennessee, Maryland and New Jersey.

LIMBINARIA MULTIPUNCTATA Swartz, n.sp.
Text-fig. 4a,b

Shell proper subelliptical in outline, truncated dorsally by straight hinge which is about five-sixths of greatest length. Cardinal angles subequal, obtuse but prominent. Terminal and ventral margins proper are rounded; in one dimorph a frill of moderate width extends submarginally from posterior cardinal angle to a point in front of middle of ventral margin.

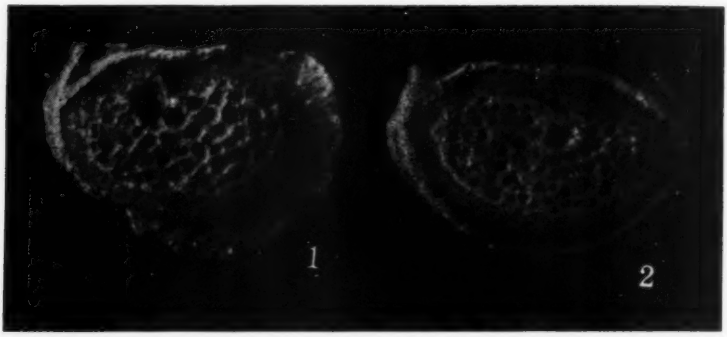
Surface of valve is moderately convex. A large, somewhat elevated, obliquely elongated medial region is irregularly marked by moderately coarse puncta, about 70 to 80 in number, and there is one larger pit anterodorsal to midpoint. A narrow ridge lies near and about parallel to median part of dorsal margin; it angles downward anteriorly and extends nearly to anterior margin; posteriorly, there is a less pronounced downward bend to this ridge. In frill-less dimorph there is a low, ventral submarginal ridge, lying about along line of attachment of frill of other dimorph, and becoming weaker along ends of valve; in frilled dimorph a comparable ridge is weakly developed close to anterior edge of valve.

The frill bearing, holotype valve measures length 0.85 mm., height 0.70 mm., height apart from frill about 0.50 mm.

Relationships.—Limbinaria multipunctata has been studied by Swartz in the course of an investigation of ostracodes of the Late Silurian Tonoloway limestone of Virginia and some nearby areas in West Virginia and Tennessee; it is described in the present paper in order to introduce the genus *Limbinaria*, which is represented by two species in the collections from the William Nearpass quarries area.

Although only a few specimens of *Limbinaria multipunctata* have been found at this time, preservation is satisfactory to show their ornament and the dimorphic characters.

Occurrence.—Very rare, *Hindella congregata* beds of the Tonoloway limestone, gap



TEXT-FIG. *4—Limbinaria multipunctata* Swartz, n. gen., n. sp. *1.* The holotype female left valve; ×45, showing the characteristic surface ornament and dimorphic flange. The largest depression is a break in the wall of the valve; the normal pit presumably indicative of the adductor location is slightly posterior to the lower end of the break. *2.* A nearly perfect male right valve ×45. The submarginal rim is almost perfectly preserved; the surface puncta are not as coarse as those of the holotype, and in part are clogged with matrix. *Hindella congregata* beds of Tonoloway limestone, gap in Little Mountain at Healing Springs, Virginia.

in Little Mountain at Healing Springs, Virginia; very rare, Tonoloway or Sneedville limestone, Mulberry gap, Tennessee.

LIMBINARIA PAUCIPUNCTATA Swartz & Whitmore, n. sp.
Pl. 103, fig. 9,10

Shell of non-frilled dimorph subovate in outline, truncated dorsally by straight hinge extending for nearly nine-tenths of greatest length. Anterior cardinal angle prominent, about a right angle, set off by a gentle subjacent emargination. Posterior angle slightly obtuse. Terminal margins rounded, posterior margin extended slightly beyond hinge. Ventral margin convex, somewhat fuller posteriorly than anteriorly, almost subangulate post-medially at position of greatest height, which is about three-fourths of greatest length.

Right valve overlaps gently on left along free margins.

Surface of valve strongly convex, the convexity strongest below and somewhat behind center of valve, the slopes to ventral and posterior margins distinctly steeper than those to dorsal and anterior edges. In non-frilled dimorph, a low ridge extends close to and parallel to hinge edge of valve, angling downward in vicinity of anterior cardinal angle, and a low ridge more or less continuous with dorsal ridge also parallel free margins. Within space enclosed by submarginal ridges, a comparatively large, elevated area is marked by rather widely spaced, moderately coarse pits, about 20 in number, and there is one much stronger, dorso-submedian pit that is located slightly anterior to midlength of valve; from posterior and ventral margins of the pitted area, surface descends abruptly toward submarginal ridge; anteriorly and dorsally the slope is more gentle, margin of elevated area is poorly defined, and general surface pitting does not as a rule extend dorsal to a line running through submedian pit.

In the frilled, presumably female dimorph, a smooth submarginal frill or flange extends along posterior portion of valve, and continues with gradually narrowing width along half or more of ventral margin, from whence it continues as a low rim like that of non-frilled dimorph.

A male valve measures length 0.76 mm., height 0.56 mm. A female valve, including the dimorphic frill, measures length 0.84 mm., height 0.6 mm.

Relationships.—*Limbinaria paucipunctata* is similar to *L. multipunctata* Swartz, n. sp., in general shape, the ridge paralleling the dorsal and free margins that in one dimorph is expanded posteriorly and postventrally to form a dimorphic frill, the surface puncta and stronger dorso-submedian pit of the medial sculptured area. However, the medial sculptured area though proportionately larger is much less well defined, and the pits are much more widely spaced and less numerous, numbering about 20 as compared to about 70 to 80 in *L. multipunctata.*

Occurrence.—Common 1 foot above top of coralline bed of upper part of Decker limestone, in zone 2A13 of Weller (1903), at the William Nearpass quarries, New Jersey.

LIMBINARIA BIANGULATA Swartz & Whitmore, n. sp.
Pl. 110, fig. 7–9

Shell dorsally truncate, subovoid in outline; cardinal angles obtuse but well defined; anterior margin somewhat higher and fuller ventrally than posterior margin; ventral margin strongly convex; greatest height about three-quarters of length, situated somewhat anterior to midlength.

Surface of valve moderately convex. Median raised and sculptured area measures about two-thirds of length and half of height of valve; its longitudinal axis is oblique, closer to dorsal margin posteriorly than anteriorly; surface of raised area bears about eight coarse, flat-floored depressions, the dorso-median depression largest and having its floor marked by a sharply impressed, rounded pit. Broad flange surrounding median elevated area is bounded by a submarginal, well elevated, continuous ridge or rim, closely adjacent to valve edges dorsally and ventrally, more distant terminally and especially near the dorsal angles.

The larger syntype valve measures length 0.9 mm., height 0.7 mm.

Relationships.—No frill-bearing dimorph has been discovered among the observed specimens of *Limbinaria biangulata*, but the

shape of the valve, the character and extent of the submarginal rim, and the form and obliquity of the medial elevated and pitted area are so similar to the corresponding features of the non-frilled dimorph of *Limbinaria multipunctata*, that close relationship to that species appears to be assured.

Limbinaria biangulata is also very suggestive of *Octonaria altoonensis* Swartz, 1932, except that it is smaller and the medial elevated area is marked by only eight instead of twenty-three pits or depressions. No frill-bearing dimorph has been discovered in "*Octonaria*" *altoonensis*, but *Limbinaria biangulata* forms a connecting link that tends to bring this species and also the somewhat differently ornamented *Octonaria? angulata* Ulrich & Bassler, 1913, and *Octonaria muricata* Ulrich & Bassler, 1923, into the genus *Limbinaria*.

Occurrence.—The syntype valves of *Limbinaria biangulata* come from slabs of Decker limestone obtained loose in a pit near the southeastern foot of Wallpack Ridge, on the Dalton Nearpass farm, New Jersey. The slabs appear to represent a horizon near the middle part of the Decker limestone. One imperfect valve was discovered in material collected 31 feet above the base of the Decker at the William Nearpass quarries.

Family DREPANELLIDAE Ulrich & Bassler
Genus RICHINA Coryell & Malkin
RICHINA ZYGALIS Swartz & Whitmore, n. sp.
Pl. 103, fig. 7,8

Shell elongate subelliptical in outline, truncated dorsally by hinge which extends for about two-thirds of greatest length. Cardinal angles subequal, distinct but obtuse. Height about three-fourths of length. Ends subequal in curvature and extension beyond hinge; ventral margin moderately convex, somewhat fuller anterior to mid-length. Edges of valve lie about in a plane; details of hinge and overlap not determined.

Surface of valve moderately convex, rising steeply from margins. Median sulcus is slightly less than one-half of distance from anterior end, and has a small rounded depression about one-fourth distance below dorsal margin, that presumably reflects internal adductor scar. Anterior to sulcus and closely adjacent to it is a well-elevated, rounded node, surmounted by a tiny point or spinelet; posterior to sulcus and somewhat farther from it is a conical node with pointed summit. A weak yoke connects these nodes around ventral end of sulcus; yoke extends ventrally from anterior node as a narrow, not quite vertical limb, then bends sharply upward toward posterior node, broadening as a low swelling and then becoming low and almost obsolete.

General surface is minutely punctate.

The syntype left valve measures length 0.97 mm., height 0.76 mm.

Relationships.—*Richina truncata* Coryell & Malkin, 1936, has obtuse cardinal angles, and one rounded, one conical node much as in *R. zygalis*. There is, however, little if any suggestion of a yoke connecting the dorsal nodes, the surface is described as being finely granulose rather than punctate, and the ends of the shell are more unequal.

The genus *Richina* was compared by Coryell & Malkin (1936) with *Ulrichia* Jones, 1890. In form of the dorsal nodes and lack of marginal ridge, *Richina* is very much closer to the section of *Bollia* represented by *Bollia hindei* Jones, 1890, and *B. widderensis* Coryell & Malkin, 1936, and further resemblance to the *Bollia* species of this type is furnished by the yoke-ridge of the new *Richina zygalis*.

Occurrence.—Very rare, 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York.

Family HOLLINIDAE Swartz
Genus PARABOLBINA Swartz
PARABOLBINA CUNEOSPINOSA Swartz & Whitemore, n. sp.
Pl. 110, fig. 1–6

Shell elongate subquadrate in outline; hinge straight, extending nearly nine-tenths of length of valve; cardinal angles obtuse but fairly well defined. Curvature of anterior margin is comparatively regular; posterior margin is recessive in lower part. Ventral margin is gently convex in male valves. Greatest height of male valve is slightly more than half of length.

Surface of valve rises steeply from margins, then flattens toward broadly convex summit. Just anterior to midlength, a well-defined, subvertical sulcus extends almost

halfway from dorsal to ventral margin. Walls of sulcus are steep, about parallel; on anterior side of sulcus is an obscure, node-like swelling.

In male valves, there is a small, wedge-like spine close to antero-ventral bend of the margin, and a similar, scarcely larger spine occurs near ventral margin about one-quarter of distance from posterior end. In female valve, there is a dimorphic frill with ends about at locations of spines of male valve. Frill has four radially-directed depressed lines, with broad intervening undulations; surfaces of undulations are marked by fine radial striae.

Surface of valve is minutely granulose.

A male valve measures length 0.68 mm., height 0.37 mm. A female valve, including frill, measures length 0.76 mm., height 0.46 mm.

Relationships.—*Parabolbina cuneospinosa* is more elongate and more equal ended than are *P. granosa* (Ulrich, 1890) and *P. limbata* Swartz, 1936. In *P. limbata* the two spines of the male valve are much stronger and more conical than are those of *P. cuneospinosa*, and in the female valve the posterior spine is retained and projects beyong the edge of the dimorphic frill.

Occurrence.—Rare 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York; very rare, 15 feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

Family BEYRICHIIDAE Ulrich
Genus VELIBEYRICHIA Henningsmoen
VELIBEYRICHIA RETICULOSACCULA
Swartz & Whitmore, n. sp.
Pl. 104, fig. 1–3

Shell subovoid in outline, truncated dorsally by straight hinge which is but little shorter than greatest length. Anterior cardinal angle somewhat obtuse; posterior angle about a right angle, its tip slightly produced. Margins of valve obscured by frill; anterior margin higher than posterior, extended slightly beyond hinge. Greatest height is about three-fourths of length, somewhat antero-median in location.

Submarginal frill is radially striate, with 9 or 10 striae in 0.5 mm.; these are crossed by more minute concentric striae, about 7 in 0.1 mm. Frill diverges from plane of conjunction of valves, so that its outer margin is bent decidedly upwards as valve is observed with plane of conjunction in a horizontal position; in male valves, frill extends along ventral margin with a width nearly one-fourth of total height of valve; frill narrows gradually as it curves upward along anterior margin; postero-ventrally, frill is abruptly narrowed, its width reduced by more than half; it then narrows gradually along posterior margin, but retains radial striae. In observed female valves, abrupt postero-ventral narrowing of frill does not occur; antero-ventrally, frill is swollen into a highly elevated, ovoid dimorphic pouch, its summit rising above that of surface lobes.

Area enclosed by frill is trilobate. Median sulcus is moderately broad, deepened ventrally, lies slightly behind midlength, and extends about three-fourths distance from dorsal margin to inner edge of frill. Anterior furrow shorter, narrower, curving along anterior margin of somewhat oblique, highly elevated median lobe. Posterior lobe is moderately convex, and is about twice as wide as small or anterior lobe. Dorsal end of anterior lobe narrows and curves posteriorward, then continues into a low dorsal crest that extends parallel to hinge margin, above upper ends of median lobe and two sulci, to about middle of dorsal margin of large lobe.

Surfaces of lobes reticulate, the pits generally irregular in shape. Surface of dimorphic pouch also reticulate, its reticulation tending to be aligned lengthwise the pouch. Below median sulcus in male valves, on ventral slope of yoke joining large lobe to median lobe, a shallow groove extends in lengthwise direction of valve; this groove has not been observed on female valves.

A male valve, including frill, measures length 1.22 mm., height 0.83 mm.; a female valve measures length 1.17 mm., height 0.89 mm.

Relationships.—*Velibeyrichia reticulosaccula* is distinguished by the coarseness of its reticulate ornament, in conjunction with the low crest paralleling the hinge and the shallow groove that in male valves lies below the ventral end of the median sulcus. The reticulate ornament of the dimorphic pouch, upon which the name is based, is beautifully preserved on the figured female valve.

In recognition of the persistence in nu-

merous related species of the combination of the radially striated frill, the three undivided lobes, and the swollen anteroventral dimorphic pouch that are characteristically displayed in the *Velibeyrichia* genotype, *Beyrichia moodeyi* Ulrich & Bassler, just as in *Velibeyrichia reticulosaccula* and *V. paucigranulosa*, the writers are using *Velibeyrichia* as a distinct genus rather than as a subgenus of *Beyrichia* as was proposed by Henningsmoen (1954b). The writers had expected to propose the same generic grouping, with the same genotype species, and had employed for it the name, *Limbabeyrichia*, in earlier drafts of the present manuscript.

One of the distinctive features of the type of frill that is developed in *Velibeyrichia*, is an inner compartmentation that was described by Swartz in a letter to N. de B. Hornibrook discussing relations of the recent South Pacific species, *Puncia novozealandica* and *Manawa tryphena*, to Paleozoic beyrichiids. (See Hornibrook, 1949.) The frill of *Velibeyrichia moodeyi*, and of various species of *Dibolbina*, *Apatobolbina* and *Eurychilina*, has been discovered by Swartz to be a doubly walled structure, having internal partitions at the locations of the radial striae of the external surface. In Swartz' opinion, the nature of this frill provides an important link between *Eurychilina* and *Velibeyrichia* that tends to support the arrangement of the eurychilinids and velibeyrichiids in a single family, in the fashion that was proposed by Swartz in 1936. It may be possible to continue to employ the name Beyrichiidae Jones for this generally frill-bearing family, since both the nonfrilled *Battus tuberculatus* Kloeden, 1834, which for many years was regarded as the genotype of *Beyrichia* McCoy, and the nonfrilled *Beyrichia kloedeni* McCoy, 1846, for which a better case as genotype can probably be made in view of remarks made by McCoy in 1851, can reasonably be interpreted as derivatives from normally frilled members of the *Eurychilina-Velibeyrichia* group.

Occurrence.—*Velibeyrichia reticulosaccula* is common 2 to 5 feet below the top of the Manlius limestone, Austin's Glen, New York. Rare 18 feet above base of Manlius limestone, William Nearpass quarries, New Jersey.

VELIBEYRICHIA PAUCIGRANULOSA
Swartz & Whitmore, n. sp.
Pl. 104, fig. 4–9

Shell subrhombic in outline, posterior cardinal angle produced so that posterior margin makes an acute angle with hinge; anterior angle obtuse with curved anterior margin extending beyond hinge for about one-eighth of valve length. Hinge extends for about seven-eighths of greatest length. Greatest height, including frill, is about two-thirds of length, and is antero-median.

Submarginal frill marked by about 12 radial striae in 0.5 mm.; it is relatively narrow, its width about one-sixth of total height of valve; its outer edge is bent decidedly upwards as valve is observed with plane of conjunction in horizontal position; frill narrows along terminal margins, without any abrupt change in width.

Surface enclosed by frill is trilobate. Median sulcus lies slightly behind midlength, and extends about two-thirds of distance from dorsal margin to inner edge of frill; median sulcus is deep ventrally, but shallows dorsally where its margins flare outwards; widened area tends to have an obscure median swelling. Anterior sulcus shallow though nearly as long as median sulcus; it is defined anteriorly by cuesta-like summit of anterior lobe. Large or posterior lobe highly elevated; its summit, posterior to deep part of median sulcus, rises about to level of median lobe. Median lobe slightly oblique, not reaching dorsal margin. Anterior lobe less than half width of posterior lobe; its posteriorly curving, dorsal tip extends into a low, narrow crest that parallels hinge margin, extending above dorsal ends of median lobe and two sulci, reaching dorsal margin of large lobe, where an obscure extension angles downward obliquely from hinge.

Dimorphic pouch of female valve is large, highly elevated, subovoid, elongated parallel to antero-ventral margin.

Surfaces of lobes bear low, obscure, distant granules; in one valve there are additional, closely spaced, much more minute granules. Ventral slope of large lobe is marked by a longitudinally disposed groove.

A male valve measures length 1.05 mm., height 0.71 mm. A female valve measures length 1.03 mm., height 0.73 mm.

Relationships.—*Velibeyrichia paucigranu-*

losa resembles *V. reticulosaccula* in the dorsal crest and ventral groove of the large lobe; but the outline tends to be subrhombic and more elongate, and the surface is granulose rather than strongly reticulate.

The longitudinally disposed groove of the ventral slope of the large lobe of both *Velibeyrichia reticulosaccula* and *V. paucigranulosa*, appears to be comparable to the "fissus" illustrated in a similar position by Henningsmoen (1954b) in specimens from the Oslo region, Norway, which he has referred to *Beyrichia kloedeni* McCoy.

The groove in the latter material appears to be a shorter counterpart of the longer grooves of *Eobeyrichia zygophora* Henningsmoen (1954b), which in turn are suggestive in their location and extent of the grooves of such species as *Conchoprimites tolli* that have been interpreted as the impression of the free margin of an early-stage valve-molt.

Occurrence.—*Velibeyrichia paucigranulosa* is common 2 feet above top of coralline bed of upper part of Decker limestone, William Nearpass quarries, New Jersey.

Genus DIBOLBINA Ulrich & Bassler
DIBOLBINA MACROSULCATA Swartz & Whitmore, n. sp.
Pl. 104, fig. 10

Shell subovate in outline, truncated dorsally by straight hinge line extending about nine-tenths of greatest length. Posterior cardinal angle acute, protuberant; anterior angle rounded. Anterior margin broadly and regularly rounded; posterior margin recessive in lower part; ventral margin moderately convex in outline.

Valve margined along free edges by a comparatively narrow frill, its width about one-tenth of greatest length of valve, its surface marked by numerous radial depressed lines that reflect partitions of inner crevice of frill. Area within frill strongly convex; greatest convexity, just posterior to lower part of median sulcus, is about one-fourth of greatest length of valve. Median sulcus deeply impressed, its walls rising steeply to adjacent lobe surfaces; sulcus is located just anterior to midlength; it extends more than half distance from dorsal margin of valve to ventral margin of frill, or two-thirds distance from dorsal margin of valve to inner margin of frill; sulcus is subvertical in disposition, but curves anteriorward in lower part. A low swelling of posterior portion of anterior lobe is suggestive of a beyrichiid median lobe. Surfaces of lobes marked by numerous shallow pits, the interspaces about equal to pit diameters.

Female dimorph not observed.

The holotype male valve measures length 1.2 mm., height 0.8 mm.

Relationships.—*Dibolbina macrosulcata* is distinguished by the convexity of the valve, and depth and length of the median sulcus.

Occurrence.—Rare 2 feet below top of Decker limestone, William Nearpass quarries, New Jersey.

Genus PSEUDOBEYRICHIA Swartz & Whitmore, n. gen.

Shell subovate to subelliptical in outline, truncated dorsally by long straight hinge, and having both cardinal angles well defined. Surface trilobate; median lobe well elevated; terminal lobes less convex, not transected by cross furrows; median sulcus strong, anterior sulcus shallow; lobate area of male valve enclosed except dorsally by an elevated, comparatively narrow rim that roughly parallels free margins; dimorphic pouch elongate, extending in genotype along free margin from anterior cardinal angle to a point behind midlength of valve; surface in genotype marked by both small puncta and comparatively coarse pustules.

Genotype.—*Pseudobeyrichia perornata* Swartz & Whitmore, n. sp.

Relationships.—On the basis of general shape of shell, trilobation of surface with its strongly elevated median lobe, anteroventral dimorphic pouch, and the strong but comparatively narrow or thin submarginal ridge, *Pseudobeyrichia perornata* appears to the writers to be closer to members of *Velibeyrichia* and *Beyrichia*, than to members of *Kloedenia* with which it might otherwise be compared. The submarginal ridge is simple as compared to the radially marked frill of *Velibeyrichia* and the spinose submarginal ridge of *Beyrichia kloedeni* as illustrated by Henningsmoen (1954b). The rim might be compared with the submarginal rim of *Nodobeyrichia* Henningsmoen (1954b), in which genus however the anterior and posterior lobes are cut by transverse furrows. The dimorphic pouch is more elongate than are those of known members of the three latter genera, and there is no suggestion of the de-

pression anteroventral to the median lobe that is well marked in many species of *Velibeyrichia*, although it is faint in the species *V. reticulosaccula* and *V. paucigranulosa* that are described in this paper. The longitudinally directed furrow of the posterior lobe of the latter two species, which has a well marked counterpart in *Beyrichia kloedeni*, is not represented in *Pseudobeyrichia perornata*.

Occurrence.—The only species now referred to *Pseudobeyrichia* is *P. perornata* of the late Silurian Manlius limestone of New Jersey.

PSEUDOBEYRICHIA PERORNATA Swartz & Whitmore, n. sp.
Pl. 104, fig. 11,12

Shell elongate subelliptical in outline, truncated dorsally by straight hinge, that extends about eight-ninths of greatest length. Anterior angle somewhat obtuse but well defined; posterior angle a little more nearly a right angle. Ends rounded, subequal in height; ventral margin medially sinuate. Height of male shell scarcely more than half of length. Edges of valve lie about in a plane.

Surface of valve well elevated, trilobate. Median sulcus well marked, subvertical; situated scarcely posterior to midlength of valve, and extending slightly more than halfway from dorsal to ventral margin. Anterior suclus shallow, poorly defined. Median lobe strongly elevated, its summit rising above plane of valve-margins for a distance about one-third of length of valve; this lobe is obpyriform in shape, its dorsal margin rounded and not reaching dorsal margin of valve; vertical axis of lobe is slightly oblique; diameter of lobe is about two-ninths length of valve. Anterior lobe relatively broad, low; posterior lobe is strongly elevated, rising with moderate slope from its posterior margin, then dropping abruptly to median sulcus. A strong, rounded node occurs at dorsal extremity of posterior lobe, and there is a similar node at dorsal end of anterior lobe; a node antero-ventral to median lobe is elongated lengthwise valve. Submarginal ridge is narrow, well elevated, extends from vicinity of posterior cardinal angle about to dorsal node of anterior lobe; ventrally and slightly posterior to midlength of valve, rim is bent slightly inward and has an angulation on its inner side; at this place it rises to a sharp eminence about twice as high as adjacent parts of rim.

In female valve, dimorphic pouch is strongly swollen, overhangs antero-ventral margin of valve, and extends from near anterior cardinal angle to a point about one-third in front of posterior margin of valve.

Surfaces of lobes and of dimorphic pouch of female valve are minutely and regularly punctate; this ornament is surmounted by scattered pustules.

In figured female valve, ventral part of median sulcus has obscure subvertical striae that may reflect adductor scar.

The holotype male valve measures length 1.0 mm., height 0.5 mm.; the figured female valve measures length 1.1 mm., height 0.8 mm.

Relationships.—*Pseudobeyrichia perornata* is unique among known species in the characters of its ornament. Its general relationships are considered in the discussion of the genus.

Occurrence.—Rare 3 feet below top of Manlius limestone, William Nearpass quarries, Wallpack Ridge, New Jersey; rare in basal foot of Manlius on Dalton Nearpass farm.

Family ZYGOBOLBIDAE Ulrich & Bassler
Subfamily KLOEDENINAE Ulrich & Bassler
Genus KLOEDENIA Jones & Holl

The genus *Kloedenia* includes trilobed Kloedeninae, in which median lobe is a rounded, elevated dorso-anteromedian knob, bounded by subvertical median and anterior sulci that commonly extend about half of distance from dorsal to ventral margin, setting off a smaller anterior and larger posterior lobe that tend to be broadly rounded with summits that do not deviate greatly from general convexity of valve surface; there is little or no development of a ventral extension of anterior sulcus; dimorphic pouch of female valve is a well-defined, antero-ventral swelling, somewhat elongated parallel to antero-ventral margin. A narrow flattened border margins free edges of each valve.

Genotype.—*Beyrichia wilckensiana* Jones of the Silurian *Beyrichia* limestone boulders of northern Germany.

Relationships.—The general character of lobation found in *Kloedenia* is shared by several other genera that differ in particular features of ornament or in character of the dimorphic swelling. Thus in *Zygobeyrichia* Ulrich there is a distinct ventral extension of the anterior sulcus and accompanying yoke-like connection of the ventral parts of the median and posterior lobes; in *Welleria* Ulrich & Bassler the margins of the dimorphic swelling are very poorly defined; in *Welleriopsis* Swartz & Whitmore, n. gen., the dimorphic pouch is an elongate, ventral rather than antero-ventral structure; *Lophokloedenia* Swartz & Whitmore, n. gen., is especially close to *Kloedenia* but its members are very closely knit by presence of a low crest that extends posteriorward from the dorsal end of the anterior lobe and terminates at a knob located in the dorsal portion of the median sulcus.

The members of *Kloedenia* that are here described from the Decker and Manlius limestones, include one group of four species that show distinct interrelationship, especially in character of the median lobe, and two additional species that diverge in aspect both from the first four and from each other.

In the group of four species, the median lobe has an obliquely directed ventral extension and hence is obliquely obpyriform. *Kloedenia sussexensis* differs from the associated *K. deckerensis* in having coarse pustules that overset the granules common to both; in both, there is some development of a zygobeyrichiid extension of the anterior sulcus, but there is little sign of the ventro-median zygose swelling of typical members of *Zygobeyrichia*. *Kloedenia duplicipunctata* and *K. crassipunctata* of the Manlius limestone resemble *K. sussexensis* and *K. deckerensis* in general shape of shell and proportionate size of lobes as well as in the obliquely obpyriform aspect of the median lobe, but lack any trace of the zygobeyrichioid furrow. In *K. duplicipunctata*, the lobe surfaces are marked by both fine and coarse puncta, whereas in *K. crassipunctata* the coarse puncta are crowded together and finer pits are lacking on the narrow interspaces.

In *Kloedenia montaguensis*, the outline is less elongate than in *K. sussexensis* and its close allies, and the obliquely obpyriform aspect of the median lobe is less pronounced; the lobes are comparatively more elevated, the median sulcus is long and deep, and the ventral region connecting the median and posterior lobes is swollen in a manner suggestive of *Zygobeyrichia* although there is no zygobeyrichiid ventral extension of the anterior sulcus. *Kloedenia montaguensis* var. *smocki* was separated from *K. montaguensis* by Weller because of greater length of the one known valve, and is of questionable significance.

Kloedenia aparchoides represents another special play upon the generic characters, in which the surface lobation and sulcation are exceptionally subdued.

Groupings such as are outlined above deserve further consideration in future studies of *Kloedenia*, in the search for better understanding of the large assemblage of species that has been referred to this genus. Investigations are especially needed that will more clearly define the characters of the genotype and its closer relatives.

Occurrence.—Silurian and Devonian, North America and Europe.

KLOEDENIA DECKERENSIS (Weller)
Pl. 106, fig. 1–6

Beyrichia deckerensis WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 256, pl. 23, fig. 11.

Kloedenia manliensis deckerensis ULRICH & BASSLER, 1908, U. S. Nat. Mus. Proc., vol. 35 (1908), p. 301. ——, BASSLER, 1915, U. S. Nat. Mus. Bull., vol. 92, p. 685. ——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 363.

Male shell dorsally truncate, elongate subovate in outline. Hinge straight for about seven-eights of greatest length. Cardinal angles obtuse, subequal. Anterior margin higher, more broadly rounded than posterior; ventral margin moderately convex, fullest in front of midlength; greatest height of valve is about three-fifths of greatest length.

Surface of valve rising steeply from margins to moderately convex general surface of lobes, the rise interrupted by a flattened border that parallels free edges. Median lobe obpyriform in outline, its ventral extension obliquely directed; this lobe does not reach dorsal margin of valve; its diameter is about one-fifth of valve length; its summit is moderately elevated, rounded. Median

sulcus is subvertical, moderate in width, and extends more than half of distance from dorsal to ventral margin. Anterior sulcus is moderately deep in upper fourth of valve; a faint ventral continuation bends posteriorward along flank of median lobe; below main part of anterior sulcus a faint, subvertical furrow crosses ventral slope of valve.

Surfaces of lobes bear minute, closely spaced granules.

The type male right valve measures length 2.24 mm., height 1.4 mm.

Relationships.—Kloedenia deckerensis closely resembles *K. sussexensis* in size, form of shell, proportions of lobes and sulci. It differs chiefly in lack of the coarse pustules that in that species overset the more minute surface granules.

Occurrence.—The holotype male left valve of *Kloedenia deckerensis* came from Weller's horizon 2A13, in upper 4 feet of Decker limestone, William Nearpass quarries, New Jersey. The species is common in new collections 2 and 3 feet below the top of the Decker at this locality.

KLOEDENIA SUSSEXENSIS (Weller)
Pl. 106, fig. 7–12

Beyrichia sussexensis WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 253, pl. 23, fig. 3,4.

Beyrichia perinflata WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 254, pl. 23, fig. 6.

Kloedenia sussexensis ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 302, pl. 38, fig. 19,20. ——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 366.

Male shell dorsally truncate, elongate subelliptical to subovate in outline. Hinge extends about seven-eights of length of shell, with region above median sulcus and median lobe tending to project slightly above hinge proper. Anterior angle obtuse; posterior angle sharp, slightly extended. Anterior margin moderately and rather regularly convex in outline; anterior end is slightly higher than posterior end and projects somewhat farther beyond limits of hinge. Ventral margin moderately convex, fullest in front of midlength; greatest height of valve is about three-fifths of length.

Surface moderately convex, rising steeply from free edges before flattening to form a rather narrow submarginal border. Median lobe rounded with a small, oblique ventral extension; this lobe does not reach dorsal margin of valve; its diameter is about two-ninths of valve-length. Median sulcus fairly deep, moderately wide, slightly enlarged ventrally along flank of median lobe, extending nearly three-fifths of distance from dorsal to ventral margin. Anterior sulcus shorter and narrower; a faint continuation bends posteriorward along flank of median lobe. Anterior lobe about three-fifths as wide as posterior lobe. Yoke-region, joining ventral ends of anterior and posterior lobes, is somewhat swollen below median sulcus and drops steeply to ventral part of submarginal border; below main part of anterior sulcus a faint depression crosses ventral slope above submarignal border.

In female valve, dimorphic pouch is strongly swollen; it lies along and overhangs part of antero-ventral border; its length is nearly two-thirds of length of valve; its dorsal margin is moderately well defined.

Surfaces of lobes bear minute, closely crowded granules surmounted by coarser, more distant pustules.

The holotype male valve measures length 2.4 mm., height 1.5 mm.

Relationships.—Kloedenia sussexensis is suggestive of *K. deckerensis*, especially as represented by the new specimens here illustrated. It differs from the latter material chiefly in presence of the coarse pustules ornamenting the surfaces of the lobes.

Female examples of *K. sussexensis* were named *Beyrichia perinflata* by Weller (1903), since their dimorphic nature was not recognized.

Male valves of *K. sussexensis* and the closely related *K. deckerensis* have a furrow on the ventral slope in line with the main part of the anterior sulcus, and hence suggest the genus *Zygobeyrichia*. The two species have been left in *Kloedenia* since the furrow is weak, and since the zygose ventral region connecting the posterior and median lobes is not markedly swollen.

Occurrence.—The type specimens of *K. sussexensis* and *K. "perinflata"* reportedly came from beds 4 to 10 feet below the top of the Decker limestone, at the William Nearpass quarries, New Jersey. No ostra-

codes were observed by the authors in new collections from these levels.

KLOEDENIA DUPLICIPUNCTATA Swartz & Whitmore, n. sp.
Pl. 106, fig. 13–15

Shell dorsally truncate, elongate subovate in outline. Hinge extends about nine-tenths of length of shell. Posterior cardinal angle protuberent, about a right angle; anterior angle obtuse. Anterior margin rather regularly rounded, projecting beyond hinge for about a tenth of shell length. Posterior margin subvertical above, rounding below into ventral margin which is moderately convex, fullest anteromedially where height of shell is about three-tenths of length.

Valve moderately convex, rising steeply from free edges, before flattening to form a submarginal border of moderate width. Median lobe rounded, obliquely obpyriform in outline, not reaching to dorsal margin; diameter is about one-fifth of length of valve. Median sulcus well defined in lower part, moderate in width, extending subvertically for about three-sevenths of distance from dorsal to ventral margin. Anterior sulcus shorter, weakening rapidly in its ventral part where it curves against median lobe. Anterior lobe nearly two-thirds as wide as posterior lobe, narrowed somewhat in dorsal part.

Surfaces of lobes are marked by rather distant, more or less irregularly spaced, coarse puncta, with finer puncta on broad interspaces. Number of coarse pits is variable; few of coarse pits occur on median lobe.

The holotype valve measures length 1.2 mm., height 0.8 mm.

Relationships.—Kloedenia duplicipunctata is closely related to *K. crassipunctata*, as is shown especially by transitional individuals in which the coarse pits are increasingly numerous. There is close agreement in the character of the coarse pits, and likewise in the proportions of the shell, of the lobes, and of the sulci.

Occurrence.—Fairly common 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York. Rare 3 feet and 15 feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

KLOEDENIA CRASSIPUNCTATA Swartz & Whitmore, n. sp.
Pl. 106, fig. 16–18

Shell dorsally truncate, elongate subovate in outline. Hinge extends about nine-tenths of greatest length. Cardinal angles well defined; posterior angle scarcely obtuse, anterior angle somewhat more so. Anterior margin higher and more regularly rounded than posterior margin, extended about twice as far beyond limits of hinge. Ventral margin moderately convex, fullest in front of midlength. Greatest height of valve is about four-sevenths of greatest length.

Surface of valve moderately convex. A submarginal, flattened border extends along free edges. Median sulcus is deepened somewhat ventrally, and extends a trifle less than halfway from dorsal to ventral margin. Anterior sulcus narrow, faint weakening ventrally, reaching about a third of distance from dorsal to ventral margin; a faint extension curves along anterior flank of median lobe. Median lobe obliquely obpyriform; moderate in size, its diameter about one-fifth of length of shell; it does not reach dorsal margin of valve; its summit rises slightly above summits of other lobes. Anterior lobe relatively wide, its width about two-thirds that of posterior lobe and almost two-fifths of length of valve.

Surfaces of lobes are coarsely punctate, the pits fairly deep, flat-floored, separated by rather narrow reticulations. There are about five pits in 0.3 mm.

In a female valve, brood pouch is elongate-ovate, overhanging anteroventral margin of valve and extending for about two-thirds of valve length. Surface of pouch is coarsely reticulate like surfaces of lobes.

A male valve measures length 1.68 mm., height 0.98 mm. A large female valve measures 2.24 mm., height 1.26 mm.

Relationships.—Kloedenia crassipunctata is an important zonal fossil for the upper part of the Manlius both near Catskill, New York, and in northwestern New Jersey, and occurs more sparingly in the lower part of the formation. It is distinguished primarily by the coarse pitting. The outline is relatively elongate for the genus.

Occurrence.—Abundant 2 to 5 feet below

top of Manlius limestone, Austin's Glen, New York. Rare to common 1½ feet, 2 feet, 3 feet, 7 to 9 feet, and 15 feet below top of Manlius limestone, William Nearpass quarries, New Jersey. Rare, basal half-foot of Manlius limestone, Dalton Nearpass farm. Rare, lower part of Manlius limestone, small quarry on Trilobite Mountain, New York, 1.2 miles northeast of Tristate village.

KLOEDENIA MONTAGUENSIS (Weller)
Pl. 108, fig. 1–8

Beyrichia montaguensis WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 267, pl. 24, fig. 23.
Kloedenia montaguensis ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 301. ——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 364.

Shell relatively high, dorsally truncate subovate in outline, with hinge about nine-tenths of greatest length. Posterior cardinal angle slightly obtuse, sharpened in many valves by a gentle subjacent emargination. Anterior cardinal angle somewhat more obtuse but well defined. Anterior margin convex, most extended and most sharply curved just above midheight, projecting beyond hinge for about one-fifteenth of length of shell. Posterior margin gently convex above, somewhat recessive below. Ventral margin in left valve tends to be truncate and almost straight for half of length of shell; in right valve this truncation is weak or lacking. Greatest height is post-median in location and is about two-thirds of length.

Surface of valve strongly convex, rising steeply from free edges to outer margin of flattened, submarginal border. In left valve, border is broadest at either end of subtruncate portion of ventral border; in right valve, border is somewhat narrowed along ventral margin.

Median lobe rounded, strongly elevated; it is large, the diameter a quarter or more of length of valve; it does not reach dorsal margin of valve. Median sulcus moderately wide and relatively deep; it is distinctly post-median in location, and extends three-fifths or more of distance from dorsal to ventral margin. Anterior sulcus moderately strong, curving along flank of median lobe. Anterior lobe sickle-shaped, its width about three-fifths that of posterior lobe.

Ventral to median sulcus, yoke connecting ventral portion of posterior lobe with region below median lobe is swollen, projects ventrally, and drops with a very steep slope to adjacent part of submarginal border.

Dimorphic pouch of female extends along and overhangs part of anteroventral margin of valve; length of pouch is about two-thirds of length of valve. Dorsal margin of pouch is moderately well defined.

Surfaces of lobes are minutely punctate in well preserved valves. The puncta with their intervening reticulations tend to be surmounted by coarse but low and fairly distant pustules. These pustules are strongly developed and numerous on dimorphic pouch of figured female valve.

The larger of the cotype, male left valves measures length 2.4 mm., height 1.6 mm. The figured female valve measures length 2.94 mm., height 1.99 mm.

Relationships.—*Kloedenia montaguensis* differs from its variety *K. m.* var. *smocki* in the proportionately greater height of the valve.

The strongly swollen ventral yoke or zygosity of *K. montaguensis* suggests the genus *Zygobeyrichia*, but the ventral prolongation of the anterior sulcus that characterizes members of that genus is not developed.

Occurrence.—William Nearpass quarries, New Jersey, 1½ to 3 feet, 6 to 8 feet, and 13 feet below top of Manlius limestone.

KLOEDENIA MONTAGUENSIS var. SMOCKI (Weller)
Pl. 108, fig. 9,10

Beyrichia smocki WELLER, 1903, Geol. Survey New Jersey, vol. 3, p. 268, pl. 24, fig. 24.
Kloedenia smocki ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 302. —— BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 365.

Restudy of the holotype specimen of *Beyrichia smocki* Weller shows it to be a right valve which in form and proportions of lobes, sulci and border agrees closely with valves of *Kloedenia montaguensis*, except that the whole valve is more elongate than is normal for the latter species, and the surface does not show the fine punctation that is well developed in most of its studied examples. The ratio of length to height in the specimen of *K. m.* var. *smocki* is 1.73 to 1 as compared to 1.5 to 1 in the larger of the cotype valves of *K. montaguen-*

sis. The border is much narrower ventrally in the holotype of *K. m.* var. *smocki* than in the cotypes of *K. montaguensis*, but this reflects the fact that the cotype specimens of *K. montaguensis* are left valves; in right valves of *K. montaguensis* the border is narrowed ventrally about as in the holotype right valve of *K. m.* var. *smocki*.

It appears at this time that *K. m.* var. *smocki* can not be separated from *K. montaguensis* except as a questionable variety; it should not be accorded even this status unless further collecting should give evidence that it is representative of an assemblage of elongate, smooth-surfaced individuals. It is not unlikely that the elongation of *K. m.* var. *smocki* may be due to distortion rather than a difference of original growth, and that the apparent smoothness of surface is due to imperfect preservation. The single specimen does not give adequate answer to the problem.

The specimen of *K. m.* var. *smocki* measures length 2.6 mm., height 1.5 mm.

Occurrence.—The holotype valve of *K. m.* var. *smocki* came from beds 13 to 23 feet above the base of the Manlius at the William Nearpass quarries, New Jersey, in horizon 2A25 of Weller's section.

KLOEDENIA cf. K. MONTAGUENSIS (Weller)
Pl. 108, fig. 11–13

Associated with typical examples of *Kloedenia montaguensis* in the upper part of the Manlius limestone at the William Nearpass quarries, are smaller and proportionately somewhat longer *Kloedenia* valves in which the yoke connecting the ventral end of the posterior lobe with the region below the median lobe is less strongly swollen than is normal for that species. These smaller valves do however resemble *K. montaguensis* in form and large size of the median lobe, in the sickle-like form of the anterior lobe, and in character of the surface puncta. It is reasonably plausible that these valves represent immature individuals or at least immature molts of *K. montaguensis*, that had not fully developed the adult characters of the species. They are separately listed here and on the accompanying plate, to draw attention to both their differences and similarities.

A male left valve of this smaller group measures length 1.8 mm., height 1.1 mm., as compared to length 2.4 mm., and height 1.6 mm. for the cotype male left valve of *Kloedenia montaguensis* illustrated in Pl. 108 fig. 3.

Occurrence.—The specimens here described were obtained at 1½, 2, and 7 to 9 feet below the top of the Manlius limestone, at the William Nearpass quarries, New Jersey.

KLOEDENIA APARCHOIDES Swartz & Whitmore, n. sp.
Pl. 103, fig. 11–14

Shell dorsally truncate, subovate in outline; hinge margin straight, about nine-tenths of greatest length; anterior cardinal angle obtuse, posterior angle nearly a right angle. Anterior margin convex in outline, fuller in front of midlength.

Hingement and overlap not observed.

Surface of valve moderately convex, weakly trilobate, the two sulci shallow and intervening median lobe low. Median sulcus is located slightly posterior to midlength (six-tenths from anterior margin in a representative male valve), and its ventral end is about one-third distance from dorsal margin. Anterior sulcus is similar in length, situated about halfway from median sulcus to anterior margin. A broad flattened border parallels free margin. In female valve, dimorphic pouch extends along antero-ventral and medio-ventral regions for about three-fourths length of valve.

In the illustrated female valve (Pl. 103, fig. 13) there is a rounded spot at ventral end of median sulcus, evidently reflecting the adductor scar.

A male valve measures length 2.5 mm., height 1.45 mm.

Relationships.—The bisulcation and trilobation of *Kloedenia aparchoides* are subdued, giving the species an *Aparchites*-like aspect as compared to more characteristic members of *Kloedenia*. Nevertheless, the trilobation is appreciably developed, and the dimorphic pouch is of normal *Kloedenia* type. The weak trilobation of *K. aparchoides* helps to show that the essentially non-sulcate *Saccarchites saccularis* may with reasonable assurance be accorded membership in the Kloedeninae. The adductor scar marks of

Kloedenia aparchoides and *Myomphalus dorsinodosus* are comparable to those of *Saccarchites saccularis.*

The weak trilobation, broad submarginal border and elongate, unequal-ended form provide distinctive specific features for *Kloedenia aparchoides.*

Occurrence.—Lower part of Manlius limestone, quarry near lane ascending eastern side of Trilobite Mountain, New York, and at quarries on Dalton Nearpass farm, New Jersey.

Genus LOPHOKLOEDENIA Swartz & Whitmore, n. gen.

Shell dorsally truncate, subovoid; hinge margin straight and long; cardinal angles well defined; surface trilobate; median lobe rounded, bordered by subvertical median and anterior sulci that extend about halfway from dorsal to ventral margin; anterior and posterior lobes broadly convex, confluent ventrally with broadly convex general surface of valve; dorsal end of anterior lobe continues into a low and narrow ridge or crest that extends posteriorward dorsal to median lobe and terminates at a low node in dorsal part of median sulcus; a narrow flattened border parallels free margins; dimorphic swelling is well defined, anteroventral in location.

Genotype.—Beyrichia manliensis Weller.

Relationships.—The known members of *Lophokloedenia* agree in shell morphology with *Kloedenia* as now understood, except for the narrow dorsal ridge or crest that extends posteriorward from the dorsal end of the anterior lobe and terminates in a

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EXPLANATION OF PLATE 107

FIG. *1–9—Lophokloedenia manliensis* (Weller). *1,2,* Side and dorsal views of the holotype male left valve, ×17 and ×22, respectively, showing the wide border, the regular surface puncta, the small node in the dorsal part of the median sulcus and the low ridge by which it is connected to the dorsal end of the anterior lobe, the vertical sides and gently convex summit of the median lobe. New Jersey Geological Survey Coll. 7341. *3–5.* Three male left valves, ×20, showing constancy of form and ornament, the broad ventral section of the border with its medially truncate outline. *6–8,* Three male right valves showing narrower border, and the persistently greater length of this valve with greatest height about at midlength. *9,* A female left valve, ×17, believed to belong to this species. *1,2,* from William Nearpass quarries, New Jersey, 2 to 6½ feet above base of Manlius limestone (2A22); *3,* from same quarries, 2 feet above base of Manlius limestone; *4,5,8,* from quarries near lane on Dalton Nearpass farm, New Jersey, basal 2 feet of Manlius limestone; *6,7,9,* from quarry beside lane on east side of Trilobite Mountain, 1.2 miles northeast of Tristate, Orange County, New York, Manlius limestone 40 feet below lowest exposed beds of Coeymans limestone. (p. 1069)

10–13—Lophokloedenia kummeli (Weller). *10,11,* Side and dorsal views of the holotype male left valve, ×17. The surface ornament is badly clogged with matrix, but some of the pustules surmounting the punctate-reticulate ornament are visible. The pustulose ridge extending from the dorsal end of the anterior lobe to the node in the dorsal part of the median sulcus, is well shown in the dorsal view. New Jersey Geological Survey Coll. 7323. William Nearpass quarries, New Jersey, 8 to 13 feet above base of Manlius limestone (2A24). *12,13,* Side and anterior views, ×15, of a female right valve with surmounting pustules especially well developed on the dimorphic pouch. Lane on east side of Trilobite Mountain, 1.2 miles northeast of Tristate, Orange County, New York, Manlius limestone 40 feet below lowest exposed beds of Coeymans limestone. (p. 1070)

14–18—Lophokloedenia eufimbriata Swartz & Whitmore, n. sp. *14,15,* Views of syntypes. *14,* A relatively complete male left valve, ×17, showing the elongate form, strong pustules surmounting the reticulate-punctate ornament of the lobes, the pustules of the bordering rim, and the node at the dorsal end of the median sulcus. The rounded mark in the ventral part of the median sulcus may be a reflection of the muscle scar. *15,* Post-ventral part of a right valve, ×38, showing the spinelets radiating from the actual edge of the valve. *16–18,* Three smaller male right valves, ×20; basal parts of the marginal spinelets are preserved in *16* and *17;* lack of coarse pustules in *18* may be due to immaturity. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p.1071)

19—Lophokloedenia cf. *L. kummeli* (Weller). A male left valve, ×20. This specimen is suggestive of *L. eufimbriata* in comparative length, and the surface puncta are relatively coarse. However, it agrees with *L. kummeli* rather than *L. eufimbriata* in the non-pustulose rim of the submarginal border, and in the medial straightness of the ventral outline. William Nearpass quarries, New Jersey, 1½ feet below top of Manlius limestone. (p. 1071)

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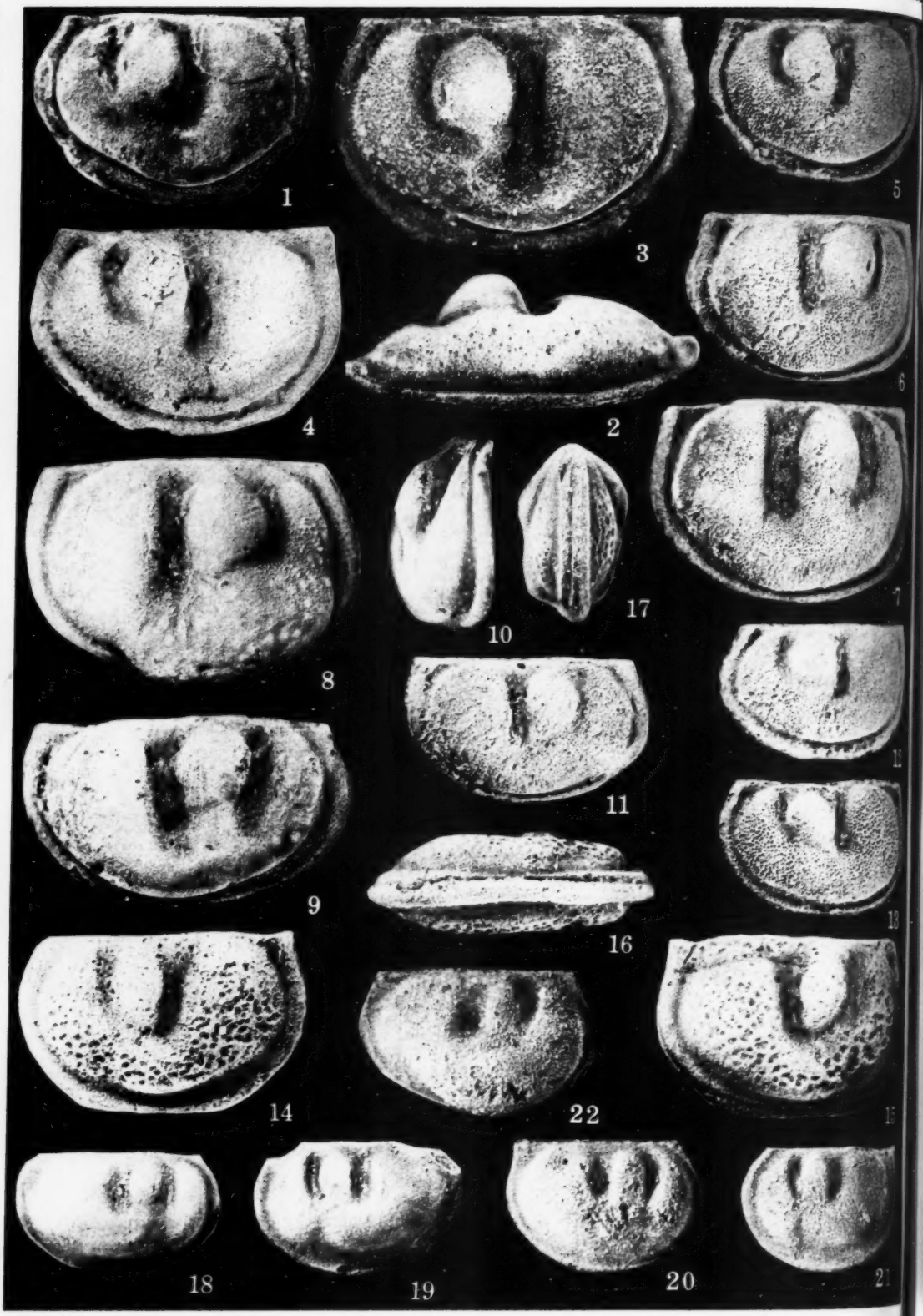
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node located in the dorsal part of the median sulcus.

Occurrence.—The three species referred to *Lophokloedenia* occur in the Manlius limestone at the Nearpass quarries, New Jersey, and at Trilobite Mountain and Austin's Glen, New York.

LOPHOKLOEDENIA MANLIENSIS (Weller)
Pl. 107, fig. 1–9

Beyrichia manliensis WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 268, pl. 23, fig. 10.

Kloedenia manliensis ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 301, pl. 38, fig. 21. ——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 363.

Shell subelliptical to subovate in outline, truncated dorsally by long straight hinge which extends for about nine-tenths of greatest length. Left valve higher than right, presumably to allow for ventral overlap on right valve. Posterior cardinal angle nearly a right angle, sharpened by a slight subjacent emargination. Anterior cardinal angle obtuse. Anterior margin rounded, extending beyond hinge for nearly a tenth of length of valve; in right more than in left valve, anterior margin is fuller below than above midheight. Posterior margin gently curved in upper part, more rapidly rounded below. Ventral margin medially truncate in outline in left but not in right valve. Great-

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EXPLANATION OF PLATE 108

FIG. *1–8—Kloedenia montaguensis* (Weller). *1–3*, The cotype male left valves, with a ventral view of the second specimen; *1* is ×17, *2* is ×21, *3* is ×23. The wide, ventrally truncated marginal border, large median lobe, long median sulcus, and strong ventral zygosity yoking the median and posterior lobes, are well shown. The minute surface punctation is visible in fig. *2*, and the surmounting pustules can be observed on the anterior lobe. *4,5*, Two male left valves, ×14 and ×16, respectively; in *4*, the deep part of the median sulcus may reflect the adductor location. *6,7*, Two male right valves, ×13 and ×21, respectively, showing proportions of valve, form of ventral zygosity, ventral narrowness of marginal border, and lack of truncation of curvature of ventral margin. In *7*, the pustules surmounting the general punctation are well shown on part of the posterior lobe. *8*, A female right valve, ×10. The surface pustules are strongly developed, especially on the dimorphic pouch. *1–3*, New Jersey Geological Survey Coll. 7336, William Nearpass quarries, New Jersey, beds 2A26, 23 to 35 feet above base of Manlius limestone. Other specimens are also from the Manlius limestone at this locality; *4* is from beds 3 feet below top of Manlius; *5* and *7* are from beds 1½ feet below top; *6* and *8* are from beds 7 to 9 feet below top. (p. 1066)

9,10—Kloedenia montaguensis var. *smocki* (Weller). Side and posterior views of the holotype male right valve, ×22, showing the similarity to *K. montaguensis* proper, but the lesser height of the valve and the smooth lobes. The elongation may be due to distortion. New Jersey Geological Survey Coll. 5934, William Nearpass quarries, New Jersey, beds 2A25, 13 to 23 feet above base of Manlius limestone. (p. 1066)

11–13—Kloedenia cf. *K. montaguensis* (Weller). A "male" right valve and two "male" left valves, ×20. These small specimens probably are immature examples of *K. montaguensis*, but differ appreciably from the larger valves. In *12* and *13* especially, the strong ventral zygosity of typical, larger specimens of *K. montaguensis* is wanting. The right valve, fig. *11*, is suggestive of *K. montaguensis* var. *smocki*. Fig. *13* especially shows the surface punctation, and the obliquely directed ventral extension of the median lobe. *11,12* from William Nearpass quarries, New Jersey, 1½ feet below top of Manlius limestone; *13* from same locality, 2 feet below top of Manlius limestone. (p. 1067)

14–17—Zygobeyrichia barretti (Weller). Left and right valve views, and ventral and posterior views of the holotype male shell, ×26, showing marginal overlap of left valve on right valve, wider and ventrally truncated submarginal border of left valve, rather narrow median lobe, and the coarse surface puncta. New Jersey Geological Survey Coll. 5933, William Nearpass quarries, New Jersey, beds 2A12, 42 to 48 feet above base of Decker limestone. (p. 1072)

18–22—Zygobeyrichia nearpassi (Weller). *18,19*, The syntype male right and left valves, ×22, showing details of the smooth-surfaced lobes. The cardinal angles are imperfect. *20,21*, A male right valve and male left valve, ×21, preserving the cardinal angles; 21 shows lack of ventral truncation that characterizes the left valve in *Z. barretti* in fig. *14*. *22*, A female right valve, ×20, showing form of the dimorphic pouch. *18,19*, New Jersey Geological Survey Coll. 6365, William Nearpass quarries, New Jersey, beds 2A13, 48 to 52 feet above base of Decker limestone; *20* from same locality, 3 feet below top of Decker limestone; *21,22* from same locality, 2 feet below top of Decker limestone. (p. 1072)

est height in left valve is three-fifths to two-thirds of length; in right valve greatest height tends to be less than three-fifths of length.

Hingement and overlap not directly observed, but from inequality in outline of valves it is reasonably clear that left valve overlaps right along ventral and probably along terminal margins.

Surface of valves moderately convex; surface rises steeply from free edges, then suddenly flattens to form a submarginal border that extends from cardinal angle to cardinal angle; border widens along ventral part of left valve, where surface is sharply inflected at outer edge of border; in right valve, border is narrowed along ventral margin.

Median lobe is rounded, knob-like, rises slightly higher than other lobes, and does not quite reach dorsal margin of valve. Median sulcus lies slightly posterior to mid-length of valve; it is well defined though moderate in width, is straight and subvertical, and reaches about halfway from dorsal to ventral margin. At dorsal end of median sulcus is a well defined node. Anterior sulcus is narrower and shorter than median sulcus, and curves along adjoining margin of median lobe. Anterior lobe is about two-thirds as wide as large posterior lobe; a narrow, low ridge curves posteriorward from dorsal end of anterior lobe and connects to node at dorsal end of median sulcus.

Surfaces of lobes are minutely, rather evenly punctate.

Though males of *L. manliensis* are common to abundant on some of studied slabs, females were not observed except for one example whose reference to the species is rendered somewhat questionable by lack of node at dorsal end of median sulcus. Anterior sulcus is weaker than in observed male valves. Dimorphic pouch is large, lies along and in part overhangs antero-ventral margin of valve, and is poorly defined along its dorsal margin.

The holotype valve measures length 2.5 mm., height 1.6 mm.

Relationships.—*Lophokloedenia manliensis* is closely related to *L. kummeli* (Weller) in general nature of the lobation, character of surface punctation, and notably in presence of the dorsal ridge and its terminal node. Left valves of *L. kummeli* tend to be appreciably more elongate than those of *L. manliensis*, and nodose thickenings surmount the punctate-reticulose surface ornament.

Occurrence.—The holotype specimen of *Lophokloedenia manliensis* came from beds 2 to 6½ feet above base of the Manlius limestone at the William Nearpass quarries, New Jersey (2A22). The species is common 2 feet above the base of the Manlius, rare 14 feet above the base in new collections from this locality; one specimen 32 feet above the base or 3 feet below the top is questionably referred to the species. *L. manliensis* is common to abundant in the basal half-foot of the Manlius on the Dalton Nearpass farm about a half-mile north of the William Nearpass quarries, and is common in lower Manlius beds, 40 feet below the lowest exposed beds of Coeymans limestone, in a quarry on the east slope of Trilobite Mountain, 2 miles northeast of Tristate, New York.

LOPHOKLOEDENIA KUMMELI (Weller)
Pl. 107, fig. 10–13

Beyrichia kummeli WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 266, pl. 24, fig. 21.

Kloedenia kummeli ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 301. —, ULRICH & BASSLER, 1913, Md. Geol. Survey, Lower Devonian, p. 531, pl. 97, fig. 16. —, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 363.

Shell more or less subquadrate in outline, with ventral margin of left valve truncate for about half of length of valve and not very divergent from hinge. Greatest height post-median, about three-tenths of length. Hinge line straight for about nine-tenths of length. Posterior cardinal angle about a right angle, set off by a slight subjacent emargination; anterior angle obtuse but sharp. Anterior margin rounded, projecting beyond hinge about one-tenth length of valve; posterior margin subvertical above, curving into ventral margin below.

Surface of valve moderately convex, rising steeply from free edges and then flattening abruptly to form submarginal border that extends from one cardinal angle to the other. On left valve, outer edge of border

is carinate, slightly upturned along ventral margin.

Median lobe rounded, its summit rising a trifle above summits of other lobes; its diameter is slightly less than a fourth of length of valve; it does not reach dorsal margin. Median sulcus is well marked, moderate in width, subvertical, and extends halfway or scarcely more of distance from dorsal to ventral margin; at dorsal end of sulcus there is a well defined node. Anterior sulcus shorter, shallower and narrower than median sulcus; it tends to curve along adjoining flank of median lobe. Anterior lobe is about two-thirds of width of posterior lobe; it narrows dorsally where it continues into a narrow ridge that extends posteriorward to node at dorsal end of median sulcus. Posterior lobe reaches greatest convexity slightly behind posterior part of median sulcus.

Dimorphic pouch of female valve is almost two-thirds as long as valve. It extends along and overhangs more anterior part of ventral margin; its dorsal margin is moderately well defined.

Surfaces of lobes and of dimorphic pouch are marked by fine, somewhat irregularly shaped pits, separated by narrow reticulations; the reticulations are locally thickened, forming irregular pustules that are especially prominent on dimorphic pouch of illustrated female valve.

The holotype male valve measures length 4 mm., height 2.1 mm.

Relationships.—*Lophokloedenia kummeli* is very close to *L. manliensis* in form of lobes and sulci, presence of the peculiar node at the dorsal end of the median sulcus, and in general nature of the surface puncta. It differs in the proportionately greater length of the left valve, and in the tendency to develop pustules surmounting the general punctate-reticulate surface ornament.

Occurrence.—The holotype specimen of *L. kummeli* came from Weller's horizon 2A24, 8 to 13 feet above the base of the Manlius limestone at the William Nearpass quarries. A few poor specimens from 1½ feet below the top of the Manlius at this locality have been questionably referred to the species. It is represented by excellent but rare examples in lower beds of the Manlius, 40 feet below the lowest exposed beds of Coeymans limestone at a quarry on the east slope of Trilobite Mountain, 1.2 miles northeast of Tristate, New York.

LOPHOKLOEDENIA cf. L. KUMMELI (Weller)
Pl. 107, fig. 19

Relationships.—The occurrence of several specimens more or less intermediate in character between *Lophokloedenia kummeli* and *L. eufimbriata*, is exemplified by illustration of a male left valve from the upper part of the Manlius limestone in New Jersey. The specimen resembles *L. eufimbriata* in comparative length of valve and in coarseness of the pustules surmounting the general puncto-reticulation of the surface. However, the pustules that ornament the marginal rim in *L. eufimbrata* are wanting and the ventral margin is less convex in outline.

Occurrence.—Rare 1½ feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

LOPHOKLOEDENIA EUFIMBRIATA Swartz & Whitmore, n. sp.
Pl. 107, fig. 14–18

Shell elongate, subelliptical to subovate in outline, truncated dorsally by straight hinge that extends about nine-tenths of length of shell. In a large left valve, cardinal angles are sharp but somewhat obtuse; ends are similar in height, their rounding comparatively regular; ventral margin is moderately and fairly regularly convex in outline. In some smaller right valves, questionably referred to species since mature ornament is not fully developed, anterior margin is convexly rounded, fuller below than above; posterior margin is subvertical in upper part, recessive below; ventral margin is regularly curved, fullest anterior to midlength. Height of shell is about three-fifths of length.

Surface of valve moderately convex, rising steeply from free edges, then flattening to form a submarginal border of moderate width; border has a shallow, inner groove setting off a somewhat elevated outer rim.

Median lobe rounded, rather prominent, not reaching dorsal margin of valve; its diameter is about one-fifth of length of

valve. Median sulcus moderate in width, deepened ventrally; it is situated slightly posterior to midlength of valve and extends subvertically for nearly three-fifths of distance from dorsal to ventral margin; a mark near ventral end of sulcus in one of syntype valves apparently reflects adductor scar; a distinct node occurs in dorsal part of median sulcus.

Anterior sulcus shorter than median sulcus, its narrowed and shallowed ventral part curving along adjoining flank of median lobe. Anterior lobe about two-thirds as wide as posterior lobe, narrowed dorsally where it continues into a low, narrow ridged that connects with node at dorsal end of median sulcus.

Surfaces of lobes are marked by irregularly shaped puncta separated by narrow reticulations; in large specimens, at least, this punctate-reticulose ornament is surmounted by numerous, low but coarse pustules; comparable pustules form a row along elevated outer rim of submarginal border of free edges. In large left valves, tiny subcylindrical spinelets lying about in plane of conjunction radiate outward from actual free edge of valve.

A large male left valve measures length 3.2 mm., height 1.9 mm.

Relationships.—Lophokloedenia eufimbriata is named from the tiny spinelets that radiate from the free edges of left valves, at least at mature stages. The spinelets presumably are lacking in right valves, to allow some marginal overlap.

The close relationship of *L. eufimbriata* to *L. manliensis* and especially to *L. kummeli* is evidenced by the general form of the lobes and sulci, and presence of the small node at the dorsal end of the median sulcus. On *L. manliensis*, the surfaces of the lobes are punctate-reticulate, without surmounting pustules, and the border is smooth. On *L. kummeli*, the punctate-reticulate surface detail is surmounted by pustules, somewhat as in *L. eufimbriata*, but the pustules are weaker and less numerous, the border does not bear pustules along its outer rim, and so far as known the radiating spinelets of the free edges of the left valve are not present.

Occurrence.—Fairly common, 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York.

Genus ZYGOBEYRICHIA Ulrich

ZYGOBEYRICHIA BARRETTI (Weller)

Pl. 108, fig. 14–17

Beyrichia barretti WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 254, pl. 23, fig. 9.

Kloedenia barretti ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 301. ——, ULRICH & BASSLER, 1913, Md. Geol. Survey, Lower Devonian, p. 532, pl. 97, fig. 17.

Male shell subquadrate to almost subpentagonal in outline; hinge line straight, extending about nine-tenths of greatest length; cardinal angles obtuse, with a slight emargination below posterior angle. In left valve, ventral margin is truncate and almost straight for half of shell-length; the truncated section is not quite parallel to hinge. Anterior end extends slightly farther beyond hinge than does the other, so that swing of shell is toward anterior end, though greatest height, equalling about two-thirds of length, is about three-fifths distance from anterior end of shell.

Right valve overlaps left along free margins.

A submarginal, flattened border extends along free edges of each valve, from one cardinal angle to the other; at outer margin of border, which is rounded ventrally, more angulated terminally, the valve wall bends abruptly downward to form flanges by which left valve overlaps on right.

Surface within border moderately convex, rising steeply from ventral part of border, and sloping more gently toward dorsal margin, so that greatest convexity is below midheight, except for elevated summit of median lobe. Median lobe elongated in dorso-ventral direction of shell; its antero-ventral margin is oblique, defined by a moderately aburpt flattening of surface; summit of lobe slopes rather gradually toward hinge. Median sulcus is just posterior to midlength of valve; it is deepened in its ventral part where it extends somewhat below midheight; it is not quite perpendicular to hinge but swings slightly toward anterior end of shell. Anterior sulcus is weaker than median sulcus; its shallow ventral extension curves along flank of median lobe; a shallow depression extends upward from ventral margin, about in line with main part of anterior sulcus, and helps to define the moderately swollen, ventral zygosity that

tends to join ventral parts of posterior and median lobes. Posterior or large lobe nearly twice as wide as anterior lobe.

Surfaces of lobes are marked by irregularly shaped, coarse, flat-floored pits, the interventing reticulose ridges wide, irregular.

The holotype shell measures length 2 mm., height 1.1 mm.

Relationships.—The large, irregularly shaped, flat-floored pits of *Z. barretti* provide a very distinctive character for the species.

The holotype of *Z. barretti* furnishes one of the rare examples of conjoined valves in the Kloedeninae, and is of interest because it gives information about the marginal overlap of the valves. The zygobeyrichiid ventro-median swelling and post-median, subventral furrow are well marked.

Occurrence.—According to Weller's records, the type specimen of *Zygobeyrichia barretti* came from the upper part of the Decker limestone, from the beds numbered 2A12 in his description of the William Nearpass section. These beds are above the range of *Chonetes jerseyensis*. Specimens obtained in Pennsylvania by F. M. Swartz occur in abundance at the base of the *Chonetes jerseyensis* zone of the Keyser limestone.

ZYGOBEYRICHIA NEARPASSI (Weller)
Pl. 108, fig. 18–22

Beyrichia nearpassi WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 255, pl. 23, fig. 7,8.

Kloedenia nearpassi ULRICH & BASSLER, U. S. Nat. Mus., Proc., vol. 35, p. 301, 304, fig. 55,56. ——, ULRICH & BASSLER, 1913, Md. Geol. Survey, Lower Devonian, p. 530, pl. 97, fig. 12,13.

Male shell subelliptical in outline, truncated dorsally by long hinge which is about five-sixths of greatest length of shell. Cardinal angles well defined, anterior angle more obtuse than the other. Posterior margin gently curved in upper part, recessive below; anterior margin more regularly curved, fuller below, extending about twice as far beyond hinge as does posterior margin. Ventral margin moderately convex. Greatest height about two-thirds of greatest length.

A submarginal, flattened border extends along free margins from one cardinal angle to the other, and is somewhat broader ventrally than along terminal margins; border is wider in left valve than in right; apparently reflecting marginal overlap by left valve.

Surface enclosed by flattened border is moderately convex. Posterior lobe is strongly convex, almost as broad as the other two lobes combined. Median lobe is subglobular, its summit rising about as high as that of posterior lobe, and sloping gradually toward hinge margin. Median sulcus lies almost exactly at midlength, is deepened ventrally, and extends about halfway from dorsal to ventral margin. Anterior sulcus is narrower than median sulcus, curves slightly along flank of median lobe; it does not reach quite to midheight, but passes ventrally into an obscure prolongation that deepens as it extends down the ventral slope.

Surfaces of lobes are smooth.

In a female vale, the antero-ventral dimorphic pouch is moderate in size, not very well defined dorsally, and overhangs marginal border.

A male valve measures length 1.5 mm., height 0.9 mm. A female valve measures length 1.5 mm., height 1.0 mm.

Relationships.—*Zygobeyrichia nearpassi* differs from *Z. barretti* in the convexity in outline of the ventral margin of the left valve, as well as in absence of the strikingly developed pits of the lobe surfaces.

Occurrence.—Very abundant in upper 4 feet of Decker limestone, at horizon 2A13 of Weller's section, William Nearpass quarries, New Jersey.

Genus MYOMPHALUS Swartz & Whitmore, n. gen.

Shell dorsally truncate subovoid, the hinge margin straight and long, the cardinal angles well defined. Median sulcus weak, bordered on each side by a rounded knob. Dimorphic pouch poorly defined, elongate, typically extending along middle and anterior parts of ventral margin.

Genotype.—*Myomphalus dorsinodosus* Swartz & Whitmore, n. sp.

Relationships.—*Myomphalus dorsinodosus*, the only species now referable to *Myomphalus*, is somewhat suggestive of *Mes-*

omphalus Ulrich & Bassler in elongation and longitudinal direction of the dimorphic pouch, and the two nodes are suggestive of those shown in the original figures of *Mesomphalus hartleyi*. In *Mesomphalus*, however, the dimorphic pouch is far better defined and is located along the middle of the ventral margin; the node behind the median sulcus has proven to be very weak; the node shown by the artist in front of the median sulcus is obscure if not non-existent; furthermore, male valves of *Mesomphalus* have a peculiar longitudinal crease that is lacking in *Myomphalus dorsinodosus*. *Myomphalus dorsinodosus* is probably best regarded as a peculiar, not truely lobate offshoot of *Kloedenia*; *K. aparchoides* of the present paper appears to be a comparatively close relative, even though it preserves the trilobation of *Kloedenia* and lacks subdorsal nodes of the type present in *dorsinodosus*.

The name *Myomphalus* has been used in recognition of the strong muscle marks of the two figured female valves of *M. dorsinodosus*.

Occurrence.—Rare to common near base of Manlius limestone, Dalton Nearpass farm, New Jersey, and quarry on east side of Trilobite Mountain, New York.

MYOMPHALUS DORSINODOSUS Swartz & Whitmore, n. sp.
Pl. 103, fig. 15–17

Male shell subovate in outline, truncated dorsally by straight hinge extending about three-fourths of greatest length. Cardinal angles about equally obtuse, fairly well defined. Anterior end higher than posterior, more broadly rounded and extending slightly farther beyond hinge; posterior end recessive below. Ventral margin moderately convex. Greatest height lies about two-fifths of distance from anterior end, and is about seven-tenths of length. Details of hinge and overlap not determined.

Surface of valve moderately convex, with a narrow, submarginal flattening or border along free edges. Two small, rounded nodes occur near dorsal margin, one on each side of weak median sulcus; more posterior node is slightly posterior to midlength and lies close to dorsal margin; more anterior node is slightly smaller, lies just anterior to midlength, is farther from dorsal margin, and in figured male valve has an oblique depression along its antero-dorsal margin. In each of two figured female valves, there is a circular spot about one-third below dorsal margin, directly below the depression or obscure median sulcus located between dorsal nodes; the spot is circumscribed by a depressed line, and evidently is an external reflection of adductor scar of inner surface of valve.

In female valves there is a large ventral dimorphic swelling, its longitudinal axis roughly parallel to that of valve; anterior end of swelling extends to anterior end of valve; posterior end is about one-quarter of distance from posterior end of valve. Dorsal margin of the swelling is very poorly defined; ventrally, the swelling overhangs edge of valve.

Surface of valve is ornamented by very obscure, distant granules.

The figured male valve measures length 1.8 mm., height 1.1 mm. The large female valve measures length 2.3 mm., height 1.5 mm.

Relationships.—*Myomphalus dorsinodosus* is *Kloedenia*-like in general form of valve, straightness of hinge and form of dimorphic pouch, and is clearly a member of the Kloedeninae. However, the bisulcation and trilobation of *Kloedenia*-type are obscure, and the two dorso-submedian knobs seem to be unmatched in previously described Kloedeninae.

Occurrence.—Rare in basal 2 feet of Manlius limestone, Dalton Nearpass farm section, Wallpack Ridge, New Jersey; rare in Manlius limestone 40 feet below lowest exposed Coeymans limestone, at a quarry near road up the east side of Trilobite Mountain, 1.2 miles northeast of Tristate, New York.

Genus WELLERIOPSIS Swartz & Whitmore, n. gen.

Trilobed, *Welleria*-like Kloedeninae, in which dimorphic pouch forms a sausage-like swelling that extends virtually the entire length of ventral part of female valve, and tends to be fairly well defined along its upper margin. Dorso-median lobe rounded, knob-like, not reaching dorsal margin of valve; median sulcus well defined; anterior sulcus almost obsolete; a narrow border parallels free margins.

Genotype.—*Welleriopsis diplocystulis* Swartz & Whitmore, n. sp.

Relationships.—Male valves of *Welleriopsis* have the appearance of *Welleria* Ulrich & Bassler, 1923, but the dimorphic pouch of the female valve is much more elongate, is ventro-median rather than antero-median in location, and is more or less defined along its dorsal margin. *Welleria* was proposed, on the other hand, because in *Welleria obliqua* Ulrich & Bassler, 1923, of the Tonoloway of Maryland, the female pouch is an undefined swelling, comparable in size and location to the pouch of *Kloedenia*, but lacking dorsal definition. The undefined pouch of *Welleria obliqua* occupies only about half of length of valve.

An elongate subcylindrical, ventrally located dimorphic pouch somewhat like that of *Welleriopsis*, occurs in *Mesomphalus* Ulrich & Bassler, 1913, but in that genus the median lobe is very poorly defined and a longitudinal crease or furrow marks the ventral slope of the posterior lobe.

Occurrence.—Decker and Manlius limestones of New Jersey; questionably from the Keyser limestone in West Virginia.

WELLERIOPSIS DIPLOCYSTULIS Swartz & Whitmore, n. sp.
Pl. 105, fig. 9–13

Shell relatively short, subelliptical to almost subquadrate in outline; hinge margin straight, extending nearly nine-tenths of greatest length. Anterior angle obtuse; posterior cardinal angle more nearly a right angle. Posterior margin subvertical and very gently convex in upper two-thirds, then curving more rapidly to the moderately convex, ventral margin. Anterior margin broadly convex, projecting beyond hinge for about one-tenth of valve length. Height of male valve nearly two-thirds of length.

Surface of valve rather strongly convex, reaching its maximum in antero-median part of large, posterior lobe, except for the still more highly elevated summit of median lobe. Median lobe does not reach dorsal margin of valve; it is moderate in size, slightly oblique. Median sulcus extends a trifle below midheight of valve; it is subvertical, well defined, its ventral tip curving slightly around median lobe. Anterior sulcus about obsolete, appearing only as a faint, slightly depressed line curving along flank of median lobe. Posterior lobe broad, the descent to median sulcus abrupt. A narrow border parallels free edges of valve, and is defined on its inner and outer sides by shallow grooves.

Dimorphic pouch of female valve strongly elevated, extending almost full length of valve; its dorsal margin is well defined, and lies near midheight of valve, being a little higher anteriorly than posteriorly; dorsal margin of pouch is indented beneath median lobe, tending to separate pouch into two parts. Pouch overhangs ventral margin of valve.

Surfaces of lobes finely punctate-reticulose.

A male valve measures length 0.98 mm., height 0.62 mm.; a female valve measures length 1.24 mm., height 0.84 mm. There are about 4 surface puncta in 0.1 mm.

Relationships.—*Welleriopsis diplocystulis* approaches *W. jerseyensis* (Weller) in outline and character of lobation; but the surface is finely punctate-reticulose rather than smooth, and the median lobe proportionately smaller but more elevated.

Occurrence.—Common 32, 33, and 33½ feet above base of Manlius limestone, William Nearpass quarries, New Jersey.

WELLERIOPSIS JERSEYENSIS (Weller)
Pl. 105, fig. 14–16

Beyrichia jerseyensis WELLER, 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 255, pl. 23, fig. 5.

Kloedenia jerseyensis ULRICH & BASSLER, 1908, U. S. Nat. Mus., Proc. vol. 35, p. 301.——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 362.

Male shell subovoid in outline, truncated dorsally by straight hinge that extends slightly more than three-fourths of greatest length. Posterior cardinal angle fairly sharp, slightly obtuse; anterior angle much more obtuse. Posterior margin nearly straight in upper part, curving more rapidly near midheight and swinging into gently convex ventral margin. Anterior margin strongly curved, fullest below, extending beyond hinge for about a sixth of valve-length.

Surface of valve moderately convex; greatest convexity occurs on posterior lobe just posterior to lower end of median sulcus, except for the slightly more elevated summit of median lobe. Median lobe subquadrate, not more than moderately elevated, its summit highest posteriorly; it is relatively large, its diameter about a fourth of valve

length; dorsal margin of median lobe is about one-fifth distance below hinge margin. Median sulcus is slightly posterior to mid-length; it extends as a narrow, moderately deep furrow from hinge for nearly two-thirds distance to ventral margin, with a slight anteriorward curve in its lower part. Anterior sulcus nearly obsolete, represented by an abrupt flattening which defines upper part of anterior margin of median lobe, whence a shallow vestigial depressed line extends toward hinge margin.

A low submarginal ridge parallels free edges, and is defined on both its inner and outer sides by shallow grooves. A narrow, low ridge also crosses post-dorsal corner of posterior lobe close to posterior cardinal angle.

Surface in finely preserved material is devoid of fine detail.

The holotype valve measures length 2.2 mm., height 1.4 mm.

Relationships.—Female examples of *W. jerseyensis* proper have not been discovered; but in the closely related variety, *W. j.* var. *microreticulis*, the dimorphic pouch has the exceptionally elongate, subcylindrical form observed in *Welleriopsis diplocystulis*, and its dorsal margin is indented below the median lobe. The male valves of *W. jerseyensis* approach those of *W. diplocystulis* in form, but are less subquadrate, the posterior end more extended beyond the hinge; furthermore, the median lobe is distinctly larger and not so strongly elevated, and the surface is smooth rather than finely punctate.

Occurrence.—Rare in upper 4 feet of Decker limestone, in 2A13 of Weller's section, William Nearpass quarries, New Jersey. The species has been reported from the Keyser limestone, one mile west of Tomahawk, West Virginia, but this record will need to be rechecked, with discovery of female as well as male valves.

WELLERIOPSIS JERSEYENSIS var. MICRORETICULIS Swartz & Whitmore, n. var.

Pl. 105, fig. 17–20

Male valves closely similar in outline and form and convexity of lobes to those of *Welleriopsis jerseyensis* proper; but surface is very minutely punctate-reticulate, and median lobe tends to be more rounded with median sulcus shorter and more curved. Posterior cardinal angle may prove to be somewhat sharper.

On a large female valve, dimorphic pouch is elongate, occupying full ventral half of valve, and overhanging ventral edge. Dorsal margin of pouch is weakly defined, though discernible; it is distinctly indented below median lobe.

A male valve measures length 1.82 mm., height 1.12 mm. The large figured female valve measures length 2.38 mm., height 1.54 mm. There are about 6 surface puncta in 0.1 mm.

Relationships.—The variety *W. j.* var. *microreticulis* is very close to *Welleriopsis jerseyensis* proper, and may prove to be questionable in value. Tentatively at least it is thought wise to call attention to its slight differences, since its valves from the basal part of the Manlius are persistently though very minutely punctate, whereas no such ornament is observable on the finely preserved *W. jerseyensis* specimens from the upper part of the Decker limestone. The slightly shorter and more curved median sulcus may also prove to have value, although all these small differentials need confirmation through future collecting.

As compared to the minutely punctate *W. j.* var. *microreticulis*, *Welleriopsis diplocystulis* of higher parts of the Manlius is more distinctly punctate, and the median lobe is smaller in diameter and more elevated.

Occurrence.—Common 2 feet above base of Manlius limestone, William Nearpass quarries, New Jersey.

Genus MESOMPHALUS Ulrich & Bassler

The genus *Mesomphalus* was proposed by Ulrich & Bassler (1913), using as the genotype *M. hartleyi* Ulrich & Bassler of the Keyser limestone of Maryland. Especially characteristic of the genus is an elongate, sausage-shaped dimorphic pouch, extending along the middle half or more of the ventral margin. As originally figured, *M. hartleyi* has a short submedian sulcus bordered at about midheight of the valve by one node on its anterior side, another on its posterior side. The valve surface is reticulose-papillose.

Among the ostracodes of the Decker, Manlius, and Coeymans at the Nearpass quarries and Austin's Glen are a number of species with the mesomphalid type of dimorphic pouch. These ostracodes have a peculiar longitudinal furrow that creases the ventral slope of the large, posterior lobe and in some instances extends across the anterior lobe as well. There is no more than a faint suggestion of a median lobe anterior to the median sulcus. Specimens with the same ventral crease occur in collections of F. M. Swartz from the upper part of the Keyser limestone in Virginia.

Because of the peculiar crease and lack of nodes of the type illustrated for *Mesomphalus hartleyi*, the new species were for a time thought to represent a new genus. However, Miss Jean Berdan, who was provided with photographs of our species for use in her studies of Manlius ostracodes in the Yale collections, re-examined the type of *Mesomphalus hartleyi* and has advised us that that species has a longitudinal crease and that the node before the sulcus is weak, the node posterior to it scarcely perceptible if not wholly wanting. The *M. hartleyi* specimens were subsequently examined by F. C. Whitmore, Jr.

Redescription.—On the basis of this information about *M. hartleyi*, and using also the species described in the present report, *Mesomphalus* can be redescribed as follows:

Shell subovate to subrhomboidal, truncated dorsally by long straight hinge. A well defined, subvertical median sulcus extends about halfway from dorsal to ventral margins, and is weak in its upper part; in front of this sulcus, a median lobe tends to be obscurely developed, set off by a faint anterior sulcus-like depression. In male valve, a narrow crease or depressed line extends length-wise valve, crossing part of ventral slope of posterior lobe; a faint extension of this furrow crosses anterior lobe in some species. A low rim parallels free edges; in some examples ventral part of rim is expanded and forms a narrow, ventral frill. In female valve, there is a well defined, ventromedian dimorphic pouch elongated lengthwise valve.

Genotype.—*Mesomphalus hartleyi* Ulrich & Bassler.

Relationships.—The weakly trilobate surface, longitudinal crease, and longitudinally elongate, strongly convex, medio-ventral dimorphic pouch are distinctive features of *Mesomphalus*.

The ventral frill of some valves of *Mesomphalus* is not, so far as is now known, internally compartmented in the manner characteristic of *Velibeyrichia* and its closer allies. The frill may prove to be a structure of immature female valves, that in adult females is expanded to form the dimorphic pouch. In some well-preserved valves lacking the dimorphic pouch, a ventral frill is definitely absent.

An elongate, ventral dimorphic pouch, suggestive of that of *Mesomphalus* but less elevated, is characteristic of the new genus, *Welleriopsis*. *Myomphalus* also has an elongate, but still less well defined ventral pouch.

Because the ventral frill may not be a true character of male valves, and since it seemingly lacks the internal compartmentation of velibeyrichiid type, *Mesomphalus* is for the present referred to the Kloedeninae and not to the Beyrichiidae.

Occurrence.—Late Silurian and earliest Devonian of Maryland, Virginia, New York, New Jersey.

MESOMPHALUS RHOMBOIDALIS
Swartz & Whitmore, n. sp.
Pl. 105, fig. 1–4

Shell elongate subrhomboidal in outline, length nearly twice height in observed male valves. Hinge straight for about eight-ninths of greatest length. Anterior cardinal angle obtuse; posterior angle about a right angle. Anterior margin rounded, fullest below, extending beyond hinge; posterior margin not extending appreciably beyond hinge, recessive in its lower part. Ventral margin gently convex, fuller in anterior half. Edges of valve lie in a plane.

Surface of valve moderately convex, rising steeply in male valves from free edges to a narrow submarginal border, which in a few specimens is expanded ventrally to form a thin, narrow frill. Median sulcus narrow but well marked; it lies about at mid-length and extends nearly three-fifths of distance from dorsal to ventral margin. Anterior to median sulcus is a low, obscure median lobe that is moderate in width and

does not reach dorsal margin. There is no more than a faint suggestion of an anterior sulcus.

A narrow crease or furrow extends posteriorward from beneath median sulcus, for about two-thirds distance across ventral slope of posterior lobe; crease is slightly curved, roughly paralleling adjacent part of ventral margin.

In female vale, dimorphic pouch is four-fifths as long as valve; its width in direction of height of valve is less than half its length; its ends are bluntly rounded, its dorsal margin slightly concave in outline; it is sharply defined dorsally and terminally; it lies along and overhangs ventral margin, and extends almost as close to anterior as to posterior end of valve.

Surfaces of lobes bear numerous small puncta; interspaces are about twice as wide to four times as wide as diameters of puncta and are minutely granulose.

A male valve measures length 1.27 mm., height 0.92 mm.; a female valve measures length 1.4 mm., height 0.77 mm.

Relationships.—New studies of *Mesomphalus hartleyi* Ulrich & Bassler, 1913, are needed to more fully establish its characters and to provide a basis for detailed comparisons with the *M. rhomboidalis* and *M. striatellus* of this paper.

In the specimens of *Mesomphalus rhomboidalis* from the uppermost Decker at the Nearpass quarries, the surface pits usually are numerous, so that the width of the interspaces is commonly about twice as wide as the diameters of the pits. In some specimens, however, there are fewer pits, so that the interspaces are distinctly wider.

Mesomphalus rhomboidalis is more elongate than *M. striatellus* Swartz & Whitmore, n. sp., and lacks the extensions of the longitudinal furrow that are found in the latter species.

Occurrence.—Moderately common 2 feet below top of Decker limestone, William Nearpass quarries, New Jersey.

MESOMPHALUS STRIATELLUS Swartz & Whitmore, n. sp.
Pl. 105, fig. 5–7

Shell somewhat subovoid in outline, truncated by straight hinge which extends for about three-fourths of greatest length. Cardinal angles well defined, anterior angle more obtuse than the other. Anterior margin rounded, slightly fuller below than above, extending beyond hinge about twice as far as does posterior margin, which is slightly lower, rounded, somewhat recessive in its lower part. Ventral margin gently convex. In male valve, greatest height is postmedian, about six-tenths of length. Edges lie in a plane.

Surface of valve moderately convex, rising steeply in male valves from free edges to a narrow submarginal border defined on its inner side by a distinct furrow. In holotype male valve, at least, it is reasonably clear that ventral part of border was not expanded as a frill. Median sulcus is narrow; it lies slightly posterior to midlength; it does not reach dorsal margin; its ventral end is situated about three-fifths of distance below dorsal margin. Anterior to median sulcus, there is an obscurely defined, weak median lobe, not reaching dorsal margin; there is only a faint suggestion of an anterior sulcus.

Beginning below median lobe, a narrow crease or furrow extends posteriorwards for three-fourths or more of distance across posterior lobe, curving upwards posteriorly; anteriorly, a faint extension of crease curves upward toward anterior cardinal angle.

In female valve, dimorphic pouch is well defined, sausage-shaped with ends bluntly rounded, its length more than twice its breadth; it extends along and overhangs ventral margin.

Surfaces of lobes are minutely granulose and bear a few scattered puncta.

The holotype male valve measures length 1.27 mm., height 0.78 mm.

Relationships.—No trace of the upcurved, anterior extension of the longitudinal crease or stria of *M. striatellus* has been observed in *Mesomphalus rhomboidalis*. *M. striatellus* also is proportionately shorter and higher than *M. rhomboidalis*.

The longitudinal crease or furrow of *M. striatellus* is reminscent of the grooves that parallel the free margins of the valves in species of *Ectodemites*, *Eridoconcha*, *Schmidtella*, *Conchoprimitia* and *Conchoprimites*, and that have been interpreted as edges or impressions of edges of early stage molts. (Cf. Levinson, 1951; Henningsmoen, 1954b).

Whether or not the longer crease or furrow of *Mesomphalus striatellus* and the shorter crease of *M. rhomboidalis* actually were developed in this fashion, the feature appears to be sufficiently persistent in character from specimen to specimen so that it can be employed in specific determinations.

Occurrence.—*Mesomphalus striatellus* is common 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York. A somewhat more subquadrate variety is rare at 8 to 15 feet above base of Coeymans limestone, William Nearpass quarries, New Jersey.

MESOMPHALUS sp.
Pl. 105, fig. 8

A specimen found in slabs collected near the top of the Manlius limestone at the Nearpass quarries, is suggestive of *Mesomphalus striatellus* in sparseness of surface pits, but differs in lack of an observable, anteriorward extension of the longitudinal crease as well as in greater prominence of the postdorsal region of the valve. The specimen is slightly smaller than the holotype of *M. striatellus*, measuring length 1.0 mm., height 0.6 mm., as compared to length 1.27 mm., height 0.78 mm. The specimen is illustrated as an aid to future investigations of the Manlius mesomphalids.

Occurrence.—Rare 1½ feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

Genus SACCARCHITES Swartz & Whitmore, n. gen.

Shell subovoid, truncated dorsally by straight hinge which is somewhat shorter than greatest length of shell; cardinal angles well defined; presumed anterior end higher and more broadly rounded than posterior; in a fragment of one shell, the questionably identified left valve overlaps right along free margins.

Surface of valve convex, not umbonate; sulci are not appreciably developed, although faint depressions visible with favorable cross-lighting may give an obscure suggestion of a dorso-submedian sulcus and in some specimens of an anterior sulcus, corresponding in position to the sulci of *Kloedenia*. On some well preserved valves, an external sub-ovoid median spot reflects location of adductor scar of inner surface. A low submarginal angulation borders free edges.

Female valve has a large, poorly defined dimorphic swelling that parallels and overhangs anteroventral margin.

Genotype.—*Saccarchites saccularis* Swartz & Whitmore, n. sp.

Relationships.—In form of shell, essentially non-sulcate surface and inconspicuous submarginal angulation, male valves of *Saccarchites saccularis* are reminiscent of the genus *Aparchites*. The proposed name has been chosen to emphasize both this similarity and the differentiating presence of the dimorphic "sac" or pouch, of which no counterpart is now known in *Aparchites*. Relationship to *Kloedenia* rather than to *Aparchites* is suggested by the form and location of the pouch, and by the very faint depressed lines of the genotype that correspond to kloedenid sulci. *Saccarchites saccularis* appears to be a kloedenid in which the supression of sulci observed in *Kloedenia aparchoides* is carried farther toward completion.

Structures comparable in many ways to those of *Saccarchites saccularis* are displayed by *Phlyctiscapha rockportensis* Kesling (1953) and *P. apleta* Kesling (1954), of Middle Devonian formations of Michigan. These species likewise are straight hinged, unequal ended, non-sulcate, with an inconspicuous angulation paralleling the free edges, and somewhat like *Saccarchites saccularis* have in one dimorph a poorly defined but comparatively large swelling that parallels and overhangs one ventro-terminal margin. Unlike the dimorphic swelling in *Saccarchites saccularis*, however, the swelling in *Phlyctiscapha rockportensis* and in *P. apleta* occurs toward the narrowly rounded or antiplenate end of the valve rather than toward the more broadly rounded or plenate end, and is accordingly considered by Kesling to be postventral in *Phlyctiscapha* on the same basis of comparative plenation of the ends of the shell that leads to the supposition that the pouch is anteroventral in *Saccarchites*. More objectively, perhaps, it can be said that if the more broadly rounded or plenate ends of the shells of the two genera represent equivalent ends of the original animals, whether anterior or posterior, then

the dimorphic swellings occur toward opposing ends of the shells; whereas if the dimorphic swellings of both genera occur at equivalent ends in terms of the original animals, then the comparative plenation of the ends of the shells is reversed and there should have been corresponding differences in relative development of the cephalic as contrasted with the more posterior parts of the animals. Whichever of these alternative conditions may be correct, differentiation on at least the generic level appears to be justified.

Occurrence.—Saccarchites saccularis and some comparable forms that require further study, occur in the Late Silurian Manlius limestone of eastern New York and northwestern New Jersey.

SACCARCHITES SACCULARIS Swartz & Whitmore, n. sp.
Pl. 103, fig. 18,19

Shell dorsally truncate, subovate in outline; dorsal margin straight for about four-fifths of greatest length; cardinal angles distinct, subequally obtuse; anterior margin somewhat higher and more broadly rounded than posterior margin, generally projecting somewhat farther beyond limits of hinge; greatest height about two-thirds of greatest length, located about at midlength of shell; ventral margin more convex anteriorly than posteriorly. Hinge surface not seen, but valves are equal externally in vicinity of hinge; in one fragment of a shell, free edge of questionable left valve laps over free edge of other valve.

Surface of male valve broadly convex, not umbonate, the greatest convexity about one-third of greatest length and located one-third or slightly more of distance from posterior end; a low angulation parallels free edges and sets off a narrow flattened submarginal border on anterior and posterior ends but not ventrally; some valves preserve an ovoid submedian mark that evidently reflects adductor scar of inner surface; midpoint of mark is slightly above and anterior to midpoint of valve; mark is dorsally acuminate, its point of acumination slightly more posterior in location than is midpoint of mark; dorsal to point of acumination of mark is a very faint depressed line that appears to be a vestige of a dorso-submedian sulcus, and in some valves there is an even more obscure depression about halfway farther toward anterior cardinal angle; in two observed internal molds of male valves, both of weak external depressions are represented by more distinct though shallow grooves, evidencing some thickening of floors of depressions, and in dorso-submedian groove there is a small rounded pit located about one-fifth distance above dorsal margin of impression of adductor scar, that represents an elevated point on inner surface of valve.

In female valve, a large and poorly defined dimorphic swelling borders and overhangs anteroventral margin; anterodorsal end of swelling is about one-sixth distance below anterior cardinal angle, ventroposterior end is nearly three-quarters distance from anterior end of valve.

Surface of valve and of dimorphic swelling, but not of adductor mark and border, bears minute pits, numbering about 5 in 0.2 mm., the interspaces flat and three to four times as wide as pits.

The syntype male and female valves each measure approximately length 1.8 mm., height 1.25 mm.

Relationships.—The form and position of the dimorphic pouch or swelling of *Saccarchites saccularis*, and the faint dorso-submedian and more anterior depressed lines that appear to represent kloedenid sulci, support the view that the species is a fairly close relative of members of *Kloedenia*.

Associated with the specimens having the proportions of the illustrated syntype male valve of *Saccarchites saccularis*, are other valves of lesser height in which a characteristic example measures length 1.7 mm., height 1.0 mm., so that ratio of length of height is about 1.7 to 1 as compared to 1.5 to 1 in *S. saccularis*. So far as now known, the greater comparative length reflects natural growth rather than post-depositional deformation, and among observed specimens the group does not show continuous variance with normal *S. saccularis*. In further work it may prove desirable to treat the elongate specimens as representatives of a distinct species. No pouch-bearing dimorph of comparable outline has been ob-

served in the present study, and external marks and vestiges of kloedenid sulci are obscure or wanting. In some of the specimens, the terminal submarginal borders are comparatively wide.

Another kind of variant is represented by an additional valve in the Austin's Glen collections, in which the size and shape are comparable to those of the male syntype of *Saccarchites saccularis* but the surface puncta are stronger and more numerous, and there is little evidence of an external adductor mark or of the vestiges of kloedenid sulci.

Occurrence.—*Saccarchites saccularis* is represented by five specimens of characteristic aspect from the beds 2 to 5 feet below the top of the Manlius limestone at Austin's Glen, and by one specimen from 15 feet below the top of the Manlius at the William Nearpass quarries. Seven additional specimens from Austin's Glen and three from 1½ to 2 feet below the top of the Manlius at the William Nearpass quarries, belong to the unnamed elongate form. Saccarchitid valves in which the puncta are coarser than is normal for *S. saccularis* include the one specimen from Austin's Glen and several from the basal foot of the Manlius limestone at the Dalton Nearpass quarries.

Genus PHLYCTISCAPHA Kesling
PHLYCTISCAPHA? sp.
Pl. 103, fig. 20

Relationships.—In addition to the normal examples of *Saccarchites saccularis* and the valves of the unnamed variant of comparable length but lesser height, the collections from both Austin's Glen and the Nearpass quarries include other *Saccarchites*-like specimens that are smaller and comparatively short and high, the length and height in several representative examples measuring respectively 1.4 and 1.0 mm., 1.3 and 0.95 mm., and 1.1 and 0.8 mm. In some the inequality of the ends is as marked as in the valve illustrated in Pl. 103, fig. 20, in others the ends are more equal although the direction of swing shown in the illustrated valve tends to be maintained. The maximum convexity of these valves is about half the height and generally is located about one-third the distance from the plenate or "anterior" end, whereas the maximum convexity is about one-third the distance from the antiplenate or "posterior" end in *Saccharchites saccularis*. Adductor marks have not been discovered in the small specimens, and no trace of kloedenid sulci has been observed.

It is possible that some of the small specimens of the collections may represent immature instars of *Saccarchites saccularis*. However, three well-preserved valves from the Nearpass quarries, measuring about 1.3 mm. in length and 1 mm. in height, bear dimorphic pouches and thus must be considered to be adult specimens. In these valves, the pouch occurs along and overhangs the ventro-antiplenate or "postventral" margin rather than along the ventro-adplenate or "antero-ventral" margin as in *Saccarchites saccularis;* the valves thus agree in location of the dimorphic pouches with *Phlycitscapha* Kesling, 1953, and as in *P. rockportensis* Kesling and *P. apleta* Kesling the pouches merge "postdorsally" with the general convexity of the valve, but are better defined along the "anterior" margin by an escarpment-like drop or semisulcus. The small specimens from Austin's Glen and the Nearpass quarries are hence listed under the term, *Phlyctiscapha?* sp., pending future preparation of photographs of the pouch-bearing valves.

Information about muscle scar location would be desirable in *Phlyctiscapha?* sp., as a further check on relative orientation as compared to *Saccarchites saccularis*. It is not impossible that the difference with respect to the original animals is one of direction of plenation rather than of reversal of location of the dimorphic pouches and place of maximum convexity. Such considerations will affect eventual interpretation of the biologic relationships of the two forms.

Occurrence.—The non-pouched valve of *Phlyctiscapha?* sp. that is illustrated in Pl. 103, fig. 20, was obtained in beds 7 to 9 feet below the top of the Manlius limestone at the William Nearpass quarries, New Jersey. Two well-preserved pouch-bearing specimens were obtained 2 feet below the top of the Manlius at the same locality, and a third was found at 15 feet below the top. Nonpouched valves are fairly common at 2 feet, 3 feet and 15 feet below the top of

the Manlius at the William Nearpass quarries, and also in the beds 2 to 5 feet below the top of the Manlius at Austin's Glen.

Genus BOLBIPRIMITIA Kay
BOLBIPRIMITIA LIMBATA Swartz & Whitmore, n. sp.
Pl. 104, fig. 13–17

Shell moderately elongate, subovoid in outline, truncated dorsally by straight hinge that extends about eight-ninths of greatest length. Anterior cardinal angle obtuse, posterior angle about a right angle or slightly acute. Anterior margin broadly and rather regularly rounded; posterior margin tends to be somewhat recessive in lower part; ventral margin convex. Greatest height including frill averages about two-thirds of greatest length. Hingement and overlap not observed.

Valve moderately convex; greatest convexity is just below midheight in posterior lobe. Median sulcus is narrow, lies anterior to midlength, and extends between points respectively about one-quarter and one-half distance below dorsal margin of valve. An obscure swelling anterior to median sulcus is suggestive of a median lobe. A frill or flange of moderate width extends along free margins; it is not radially striate, and inner compartmentation of velibeyrichiid type has not been observed. In female valves, there is a longitudinally elongate, ventro-median dimorphic swelling that joins with ventral part of posterior lobe in a cornucopia-like fashion.

Surface of valve where enclosed by frill is coarsely reticulate, the pits somewhat irregular in shape and without regular arrangement. Surface of dimorphic pouch of female valve is more finely pitted.

A characteristic male valve measures length 0.9 mm., height 0.6 mm. A female valve measures length 1.1 mm., height 0.7 mm. One male valve that is illustrated on an accompanying plate is unusually elongate, the ratio of height to length being 0.55 to 1 as compared to ratios of 0.65 and more to 1 in more typical specimens. The difference in ratio may have resulted from distortion during compaction of the sediment, rather than from differing growth.

Relationships.—The dimorphic pouch of *Bolbiprimitia limbata* joins with the posterior lobe in cornucopia-like form as is true in the genotype, *B. fissurella* (Ulrich & Bassler). The marginal frill or flange is stronger than in previously described species of the genus, but so far as known does not have the inner compartmentation that characterizes the frills of *Velibeyrichia* and its allies. *Bolbiprimitia teresaccula*, described on following pages, has a smooth and not a punctate dimorphic pouch.

Occurrence.—Common 2 feet above base of Manlius limestone, William Nearpass quarries, New Jersey. Also fairly common 3 feet and 7 to 9 feet below the top of the Manlius at the same locality.

BOLBIPRIMITIA TERESACCULA Swartz & Whitmore, n. sp.
Pl. 104, fig. 18

Shell subovate in outline, truncated dorsally by straight hinge that extends for about nine-tenths of greatest length. Anterior cardinal angle obtuse, posterior angle a right angle or slightly acute. Anterior margin broadly and regularly rounded; posterior margin somewhat recessive below. In the single known female valve on which species is founded, height is three-fourths of length. Hingement and overlap not observed.

Female valve rather strongly convex; greatest convexity except for dimorphic pouch is in posterior lobe about at midheight of valve. A flattened border or shoulder extends along terminal margins, and presumably would be continuous ventrally in male valves. Median sulcus is represented by a rounded umbilicus-like depression slightly anterior to midpoint of valve. Female dimorphic pouch is strongly swollen, extends along ventral margin for about five-sixths total length of valve, and merges posteriorly with ventral part of posterior lobe.

Surface of dimorphic pouch is smooth; otherwise lobate area enclosed by marginal border is coarsely reticulate, the pits somewhat irregular in shape and without regular arrangement.

The holotype female valve measures length 1.0 mm., height 0.75 mm.

Relationships.—The surface puncta of *Bolbiprimitia teresaccula* resemble those of *B. limbata* in size, irregular shape, and lack

of well-defined arrangement. The female dimorphic pouch, however, is smooth-surfaced and not punctate, is more elongate and more swollen; the median sulcus is an umbilicus-like depression instead of a vertically elongated cleft; the valve is somewhat more swollen in the region of slope to the hinge; and the shell is proportionately less elongate.

Occurrence.—The holotype female valve and only known specimen comes from 2 to 5 feet below the top of the Manlius limestone at Austin's Glen, New York.

Family KLOEDENELLIDAE
Ulrich & Bassler
Genus EUKLOEDENELLA
Ulrich & Bassler

EUKLOEDENELLA CICATRIX Swartz & Whitmore, n. sp.
Pl. 109, fig. 1–3

Male shell subrectangular in outline. Hinge margin slightly sinuate in right valve due to low, post-median dorsal crest; anterior cardinal angle rounded; posterior cardinal angle more distinct but obtuse. Anterior margin regularly convex in outline, rounding gradually into gently curved ventral margin; posterior margin gently convex in outline, bending rapidly to ventral margin.

Surface of valve moderately convex. Median sulcus is moderate in size and depth, extends to about one-third distance below dorsal margin, and is located about two-fifths of distance from anterior margin. Median lobe is small, obscure. Anterior sulcus is virtually obsolete. A distinct, narrow, low ridge or carina extends lengthwise the valve about at midheight, bending slightly downward in its anterior part; the carina dies out on both anterior and posterior quarters of valve. Surface has some small scattered pits.

In female valve, posterior quarter of valve is swollen, forming an undefined dimorphic pouch.

Relationships.—The peculiar longitudinal carina of *E. cicatrix* provides a distinctive specific feature.

Occurrence.—Rare 3 feet below top of Decker limestone, William Nearpass quarries, New Jersey.

EUKLOEDENELLA MANLIENSIS Swartz & Whitmore, n. sp.
Pl. 109, fig. 4–6

Male shell subrhomboidal in side view; dorsal and ventral margins about parallel; anterior margin rounded, fullest below; posterior margin less convex, recessive below. Anterior cardinal bend rounded, posterior cardinal angle obtuse. Ventral margin gently sinuate. In dorsal view male shell is subovate, relatively thick for genus, the ends not strongly unequal in thickness. Hinge tooth of left valve about obsolete, represented only by a gently arched projection set off on its posterior side by a small indentation that accommodates a slight projection of margin of right valve.

Surface of valve rises steeply from margins to gently convex summit of valve. Median sulcus shallow, weak, extending about one-third distance from dorsal margin, located just in front of midlength of valve. Anterior sulcus almost obsolete; located one-third distance from anterior margin.

Surface of valve probably smooth or very nearly so, the preservation somewhat imperfect in studied specimens.

Female valve distinctly longer than male specimens, swollen posteriorly into a bulbous but poorly defined dimorphic pouch.

The syntype male shell measures length 1.1 mm., height 0.8 mm. The female valve measures length 1.3 mm., height 0.7 mm.

Relationships.—*Eukloedenella manliensis* is distinguished by the location and weakness of the sulci, and the thickness of the male shell.

Occurrence.—Common 1½ feet, rare 3 feet, rare 7 to 9 feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

Genus KLOEDENELLA Ulrich & Bassler

KLOEDENELLA BIPUSTULATA Swartz & Whitmore, n. sp.
Pl. 109, fig. 7–15

Male shell subrectangular in side view. Anterior margin rounded; posterior margin comparatively truncate; ventral margin gently convex to slightly sinuate. Posterior cardinal angle obtuse; anterior cardinal bend rounded, in some specimens having a

gentle hump at hinge tooth of left valve. Height of male valve commonly is about two-thirds of length. In dorsal view, male shell is almost arrow-shaped, thickest about one-sixth distance from posterior end. Anterior hinge-tooth of left valve is moderately strong, forming a broad-based, low triangle. Left valve overlaps slightly on right along free margins.

Surface of male valve moderately convex, rising steeply with a concave curvature from posterior margin to a crest that characteristically is surmounted by two distinct nodes, one near dorsal margin and one near ventral. Median sulcus is strongly impressed, moderate in width, is located just in front of midlength of valve, and extends about two-fifths distance from dorsal to ventral margins. Anterior sulcus is narrower, slightly longer, and is located less than one-third distance from anterior margin.

Node of dorsal part of posterior crest of valve is somewhat variable, and is weakly developed in some of specimens retained in *K. bipustulata*. Post-ventral node is more stable in development.

Female valves are larger and longer than males, and have a strongly swollen though poorly defined dimorphic pouch, that modifies posterior end of valve so that nodes of male valve are wanting.

A characteristic male valve measures length 0.7 mm., height 0.45 mm. A large female valve measures length 1.0 mm., height 0.6 mm.

Relationships.—The two nodes at the summit of the posterior slope of the male valve make *Kloedenella bipustulata* an exceptionally well characterized species, that should be very useful in future zonation of the Manlius limestone.

Associated with the characteristic examples in which the two distinctive nodes are well developed, are other specimens in which the more dorsal node, especially, is variable in strength. In some of the larger male valves the more ventral node tends to become a carination, extended dorsally along the summit of the posterior slope of the valve. It may be that the differences in these male valves are in part ontogenetic.

Occurrence.—Common to abundant 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York. Common 1½ feet, rare to common 2 feet, common 3 feet, common 7 to 9 feet, rare 15 feet below top of Manlius, William Nearpass quarries, New Jersey. A variant with the posterior nodes

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EXPLANATION OF PLATE 109

All views about ×30

FIG. *1–3*—*Eukloedenella cicatrix* Swartz & Whitmore, n. sp. Views of syntypes. *1*, Male right valve, showing longitudinal ridge. *2,3*, Lateral and dorsal views of female left valve, the longitudinal ridge less strongly developed; in *3* the dorsal crest is well shown. William Nearpass quarries, New Jersey, 3 feet below top of Decker limestone. (p. 1083)

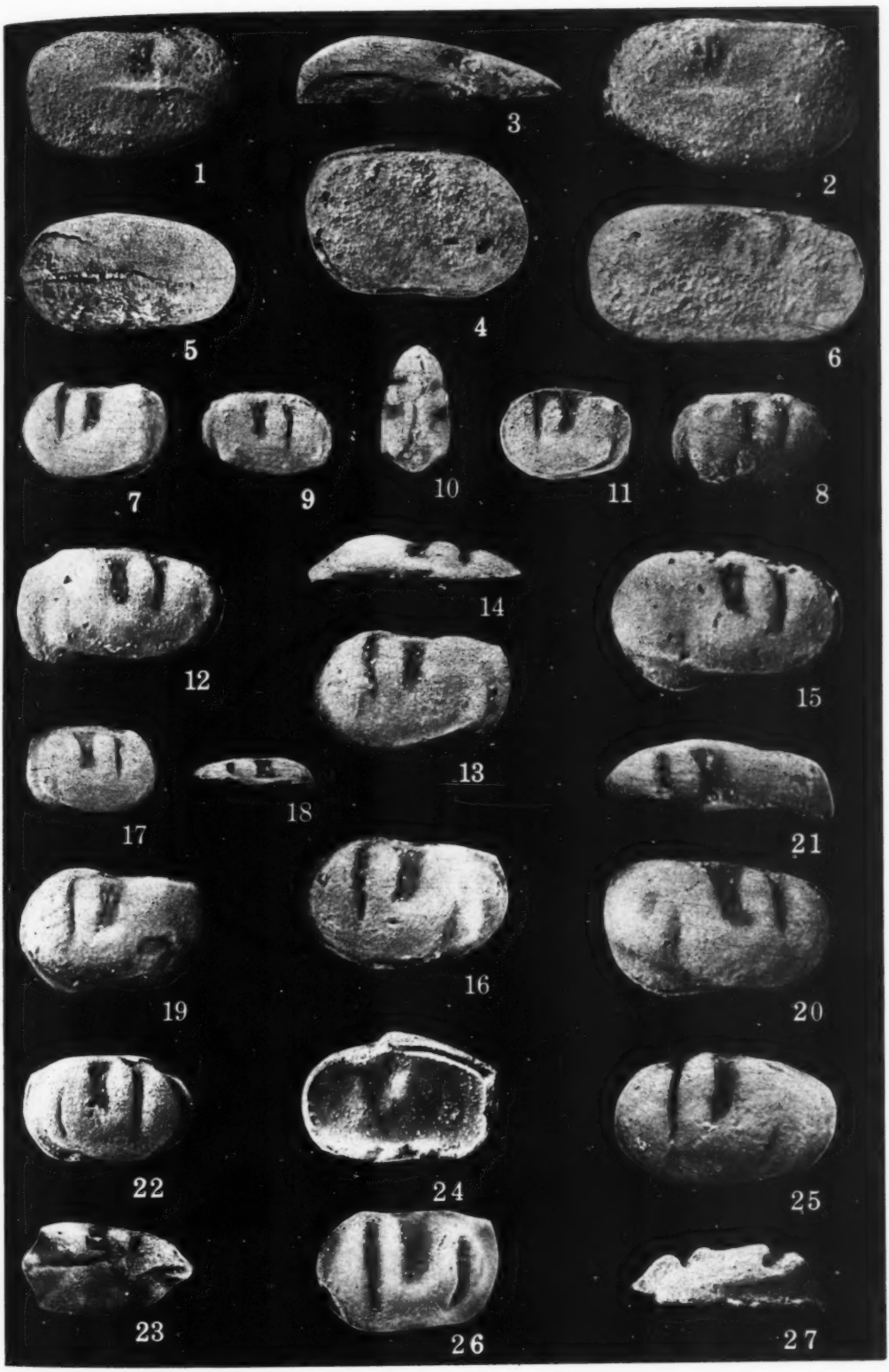
4–6—*Eukloedenella manliensis* Swartz & Whitmore, n. sp. Views of syntypes. *4,5*, Right and dorsal views of male (*?*) shell. *6*, An elongate, presumably female right valve. William Nearpass quarries, New Jersey, 1½ feet below top of Manlius limestone. (p. 1083)

7–15—*Kloedenella bipustulata* Swartz & Whitmore, n. sp. *7—11*, The syntypes. *7,8*, Male left and right valves, showing the two nodes at the crest of the posterior slope. *9–11*, Right, dorsal, and left views of a small male shell. *12*, An elongate male right valve. *13,14*, Side and dorsal views of a male left valve, a variant in which the post-dorsal node is about obsolete. *15*, A female right valve. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1083)

16–21—*Kloedenella parvisulcata* Swartz & Whitmore, n. sp. *16*, The holotype, a male left valve, showing the small post-ventral furrow, and the close resemblance to *K. bipustulata* in form and lobation. *17,18*, Side and dorsal views of a small male right valve. *19*, A male left valve questionably referred to the species. *20,21*, Side and dorsal views of a female right valve. William Nearpass quarries, New Jersey, 3 feet below top of Decker limestone. (p. 1085)

22–25—*Dizygopleura angustisulcata* Swartz & Whitmore, n. sp. *22,23*, Right and dorsal views of the holotype male shell. *24*, Interior of a male right valve, showing the longitudinal hinge-groove posterior to notch for the hinge-tooth. *25*, Female left valve. William Nearpass quarries, 3 feet below top of Decker limestone. (p. 1086)

26,27—*Dizygopleura* cf. *D. clarkei* (Jones). Side and ventral views of male left valve. William Nearpass quarries, 3 feet below top of Decker limestone. (p. 1086)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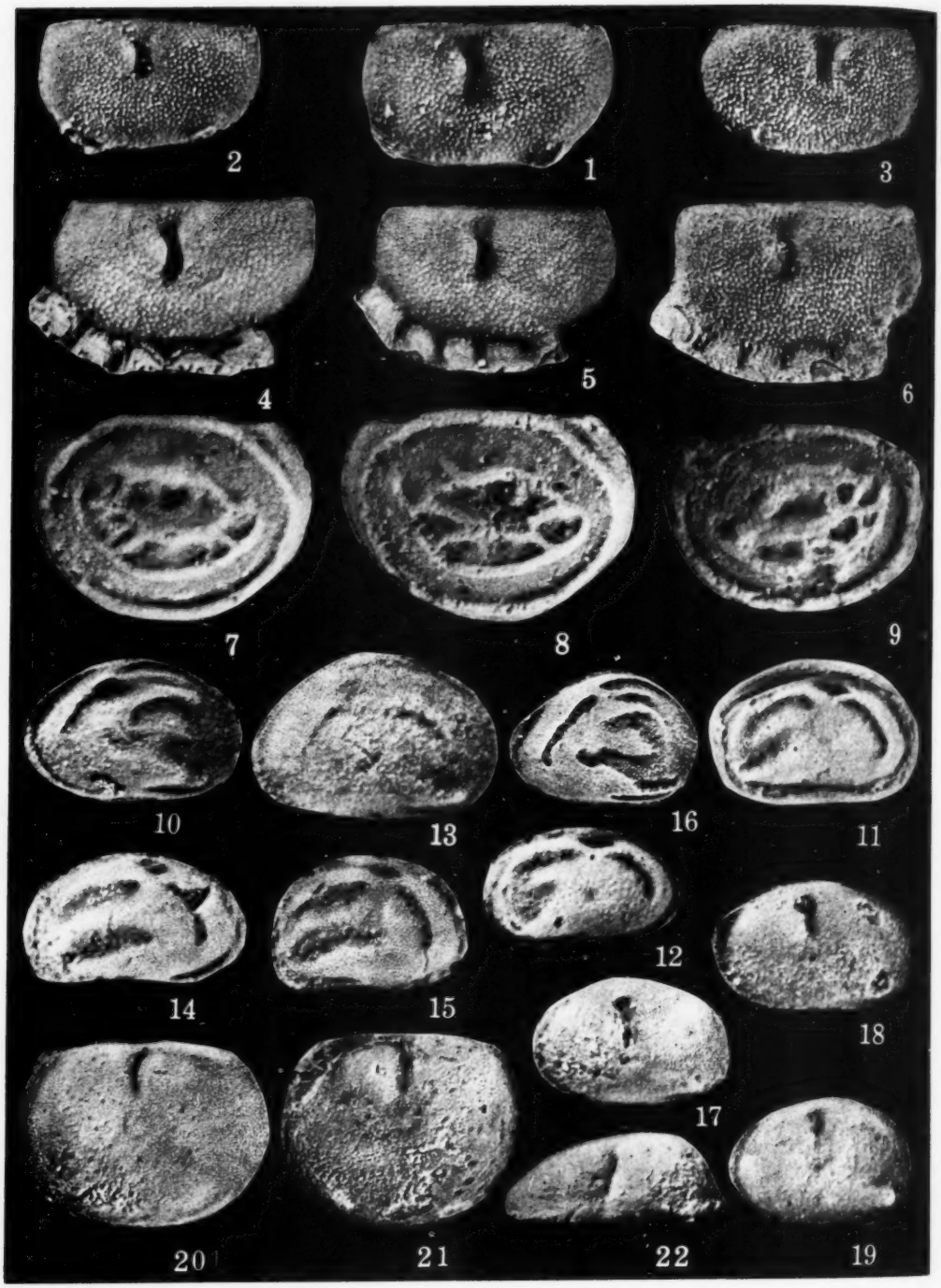
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scarcely developed, is common 2 feet above base of the Manlius at the William Nearpass quarries, New Jersey.

KLOEDENELLA PARVISULCATA Swartz & Whitmore, n. sp.
Pl. 109, fig. 16–21

Male shell subrhombic in outline; anterior margin strongly curved; posterior margin less convex and somewhat recessive below. Ventral margin varying from gently convex to slightly sinuate. Height of male valve is about two-thirds of length. Hinge-tooth of left valve is short, broad-based.

Surface of male valve moderately convex, greatest convexity behind midlength. Median sulcus well impressed, moderate in width, extending more than two-fifths of distance from dorsal to ventral margin, located slightly more than one-fourth distance from anterior margin. A short posterior sulcus creases post-ventral part of the valve, setting off a low posterior lobe at summit of steep posterior slope.

Female valve is distinctly longer than male valve, and has a strongly swollen posterior dimorphic pouch defined antero-ventrally by posterior sulcus.

The holotype male left valve measures length 0.9 mm., height 0.6 mm. A female valve measures length 1.1 mm., height 0.6 mm.

EXPLANATION OF PLATE 110

FIG. *1–6—Parabolbina cuneospinosa* Swartz & Whitmore, n. sp. *1,2*, Views, ×50, of the syntype male left valves, showing the small ventral spines, and the granulose surface. *3*, A male right valve, ×47. *4–6*, Three female left valves; *4*, ×45, *5* and *6*, ×50, showing the dimorphic frill with broad radial undulations and fine radial striae. *1–5*, from Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone; *6* from William Nearpass quarries, New Jersey, 15 feet below top of Manlius limestone. (p. 1058)

7–9—Limbinaria biangulata Swartz & Whitmore, n. gen., n. sp. *7,8*, The syntype right valves, ×45. The ornament and presumed adductor pit are exceptionally well preserved in *7*. *9*, A left valve, ×45. These specimens were photographed in *Octonaria*-like fashion with the convex margin in dorsal location, so that as now oriented the lighting is from the lower right. *7,8*, Dalton Nearpass farm, New Jersey, Decker limestone slabs loose in pit near southeastern foot of Wallpack ridge. *9*, William Nearpass quarries, New Jersey, 31 feet above base of Decker limestone. (p. 1057)

10–12—Thlipsuropsis diploglyptulis Swartz & Whitmore, n. gen., n. sp. *10,11*, Presumed left and right views of the holotype shell, ×45, showing the markedly different aspect of the opposing valves, and in 11 the overlap along all margins of the left valve on the right valve. In *11* the hinge appears to be represented by the straight portion of the contact line, to the left of the dorso-median pit. *12*, A right valve, ×45, showing better than in *11* the shortness of the more ventral of the posterior furrows of this valve. Austin's Glen, New York, 2 to 5 feet below top of Manlius limestone. (p. 1087)

13—Thlipsuropsis sp. Left view of a poorly preserved shell, ×48. This may represent *T. diploglyptulis*, but the ornament is too imperfect for confident identification. William Nearpass quarries, New Jersey, 7 to 9 feet below top of Manlius limestone. (p. 1087)

14,15—Thlipsuropsis longisulcata Swartz & Whitmore, n. gen., n. sp. The syntype right valves, ×50 and ×55, respectively, showing the long post-ventral furrow. In *14*, the triangular depression extending from the antero-dorsal furrow is a break in the shell wall. Dalton Nearpass farm, New Jersey, Decker limestone slabs loose in pit near southeastern foot of Wallpack Ridge. (p. 1088)

16—Thlipsuropsis digitata Swartz & Whitmore, n. gen., n. sp. The holotype left valve, ×34, showing the details of the furrows. Dalton Nearpass farm, New Jersey, upper part of Coeymans limestone. (p. 1088)

17–19—Parahealdia? convexoris Swartz & Whitmore, n. sp. Views of syntype left valves, ×48, ×50, and ×60, respectively. The posterior spinose projections are best preserved in *19*, although their positions are well shown by the broken bases in *18*. The strongly convex dorsal margin is abnormal for *Parahealdia* as its members have been illustrated. William Nearpass quarries, New Jersey, 7 to 9 feet below top of Manlius limestone. (p. 1089)

20–22—Bonneprimites? breviformis Swartz & Whitmore, n. sp. Views of the syntype male right and left valves, and dorsal view of the right valve, ×36. The rounded depression below the median sulcus evidently reflects the adductor scar. William Nearpass quarries, New Jersey, 1 to 2 feet above base of Decker limestone. (p. 1053)

Relationships.—*Kloedenella parvisulcata* closely resembles *K. bipustulata* in general shape of shell, and in form, size, and location of the median and posterior sulci, and of the dimorphic swelling of the female valve. It differs however in lack of the posterior nodes and in presence of a short post-ventral sulcus. In view of these marked similarities and since *K. parvisulcata* occurs in the older stratigraphic horizon, it is likely that the species is ancestral to *K. bipustulata*. This seeming relation to *K. bipustulata* has prompted the writers to place *K. parvisulcata* in *Kloedenella* rather than in *Dizygopleura*, where it might be classed because of the short post-ventral sulcus.

Occurrence.—Common at 2 feet and 3 feet below top of Decker limestone, William Nearpass quarries, New Jersey.

Genus DIZYGOPLEURA Ulrich & Bassler

DIZYGOPLEURA ANGUSTISULCATA
Swartz & Whitmore, n. sp.
Pl. 109, fig. 22–25

Male shell subrhomboid in lateral view; dorsal margin nearly straight; anterior margin strongly convex, fuller below midheight; posterior margin recessive ventrally; ventral margin straight to slightly sinuate; posterior cardinal angle obtuse; anterior cardinal bend rounded. In dorsal view, male shell is arrow-shaped, with greatest thickness about one-eighth distance from posterior margin near summits of concave posterior slopes of valves. Hinge tooth of left valve is strongly developed, triangular, bears an extension of anterior sulcus, and is bordered on its posterior side by a small tooth-like projection of margin of right valve.

Interior of a right valve shows a well-marked longitudinal groove on hinge surface posterior to sulcus accommodating tooth of left valve; groove evidently received bar-like margin of edge of left valve.

Surface of male valve rather strongly convex, rising from posterior margin with a steep, concave slope to an escarpment-like crest. Median sulcus well impressed, moderate in width, extending not quite half-way from dorsal to ventral margin, located about at midlength of valve. Anterior sulcus narrower, extending about two-thirds distance from dorsal to ventral margin, located not quite one-third distance from anterior margin. Posterior sulcus is very narrow, shallow, lies a little in front of and parallels crest at summit of posterior slope of valve, and extends from about one-quarter below dorsal margin to one-quarter above ventral margin of shell. There is a narrow flattened border along anterior margin.

In female valve, posterior end of valve is more convex, and posterior slope of valve is convex and not concave as in male valve. Posterior sulcus tends to be reduced to a narrow furrow restricted to ventral half of valve.

The holotype male shell measures length 0.87 mm., height 0.53 mm. A female valve measures length 0.9 mm., height 0.62 mm.

Relationships.—*Dizygopleura angustisulcata* is named from the distinctively narrow posterior sulcus. The anterior sulcus is relatively short for a species of *Dizygopleura*.

The longitudinal furrow of the posterior half of the hinge surface of *D. angustisulcata* may occur in many species of *Dizygopleura*, but is not readily observable in specimens from the well-lithified limestones of the Appalachian mid-Paleozoics. Such grooves do not seem to have been previously recognized in Silurian-Devonian Kloedenellidae.

Occurrence.—Common 2 feet and 3 feet below top of Decker limestone, William Nearpass quarries, New Jersey.

DIZYGOPLEURA cf. D. CLARKEI (Jones)
Pl. 109, fig. 26,27

Beyrichia clarkei JONES, 1890, Geol. Soc. London, Quart. Jour., vol. 46, p. 17, text-fig. 2.
Dizygopleura clarkei ULRICH & BASSLER, 1923, Md. Geol. Survey, Silurian, p. 698, pl. 62, fig. 31,32.——, BASSLER & KELLETT, 1934, Geol. Soc. Am., Special Paper no. 1, p. 289.

Male valve subrectangular to somewhat subrhombic in lateral view. Hinge margin straight, at least in left valve; posterior cardinal angle well defined, somewhat obtuse; anterior cardinal bend rounded; anterior margin strongly convex, slightly fuller below than above middle; posterior margin gently curved, somewhat recessive in lower part; ventral margin straight to slightly sinuate.

Surface of male valve rather strongly convex, rising steeply and with a concave slope from posterior margin and somewhat less steeply from anterior margin; general sum-

mit region, as seen in ventral view, is relatively flat from crest of anterior lobe to crest of posterior lobe. Median sulcus deeply impressed, fairly broad, extending more than half distance from dorsal to ventral margin, located about at midlength of valve. Anterior sulcus deep, moderate in width, extending about four-fifths distance from dorsal to ventral margin, located about three-tenths distance from anterior margin. Posterior sulcus deep, moderate in width, closed both dorsally and ventrally, extending from about one-quarter below dorsal margin to one-quarter above ventral margin.

The illustrated male left valve measures length 0.76 mm., height 0.53 mm.

Relationships.—The type valve of *Dizygopleura clarkei*, refigured by Ulrich & Bassler (1923), may be a female valve. Both the holotype specimen and topotype material need to be restudied to more fully establish the characters of male and female valves.

Occurrence.—The male left valve figured on an accompanying plate was obtained 2 to 3 feet below the top of the Decker limestone, at the William Nearpass quarries, New Jersey. Jones' holotype specimen came from the lower part of the Manlius limestone, near Schoharie, New York.

Family THLIPSURIDAE Ulrich
Genus THLIPSUROPSIS Swartz & Whitmore, n. gen.

Markedly inequivalved Thlipsuridae, in which the larger, left valve has a thlipsurid, posterior depressed area confluent with anteriorly projecting furrows, whereas in the smaller, right valve the thlipsurid depressed area is wanting. A narrow furrow roughly parallels the antero-dorsal margin.

Genotype.—Thlipsuropsis diploglyptulis Swartz & Whitmore, n. sp.

Relationships.—The opposing valves of *Thlipsuropsis diploglyptulis* differ so greatly in aspect that they were attributed to different genera until conjoined valves were discovered. The left valve has the appearance of *Thlipsura* whereas the right valve is suggestive of *Thlipsurella.*

The three new species here included in *Thlipsuropsis* are very close relatives and form a very compact group. In *T. longisulcata*, the post-ventral sulcus is longer than in *T. diploglyptulis;* in *T. digitata* the antero-dorsal furrow of the left valve is hooked antero-ventrally and lacks the post-dorsally located pit of *T. diploglyptulis.*

Some evidence for orientation of *Thlipsuropsis* and perhaps of *Thlipsura* is furnished by *Thlipsuropsis diploglyptulis.* In the illustrated holotype with its conjoined valves, the smaller, right valve exhibits a shallowly depressed, submedian, rounded external mark that with reasonable certainty reflects the adductor scar; if the scar is antero-median in location, the unisulcate end of the valve is the anterior end, and in the larger, left valve the thlipsurid depression occurs at the posterior end. This orientation further is favored by position of a straight portion of the dorsal contact line of the valves, that occurs above the bisulcate end of the smaller valve and appears to represent the actual location of the hinge.

Occurrence.—The three species here referred to *Thlipsuropsis* occur in the Late Silurian Decker and Manlius limestones, and Early Devonian Coeymans limestone of northwestern New Jersey and eastern New York.

THLIPSUROPSIS DIPLOGLYPTULIS Swartz & Whitmore, n. sp.
Pl. 110, fig. 10–12,13?

Shell subreniform in outline; dorsal margin convex; ventral margin nearly straight for about two-thirds length of shell; anterior margin somewhat more narrowly curved than posterior. Greatest height submedian, about five-sevenths of greatest length.

Left valve overlaps and projects well beyond right valve along all margins, so that actual contact line is visible only in right-valve view of shell. Posterior half of dorsal part of contact is straight and adjacent margins of valves are beveled, suggesting that straight section may represent location of actual hinge.

Surfaces of valves moderately convex; greatest convexity is about one-third from posterior end. In left valve, a *Thlipsura*-like, relatively depressed but nevertheless convex area borders posterior margin. Five shallow furrows extend anteriorward from depressed area; most dorsal furrow is narrow, curves forward closely adjacent to dorsal margin, and extends beyond midlength of

shell; second furrow is similarly curved, narrow, shorter; third furrow is broader, sickle-shaped, narrows anteriorly and diverges from more dorsal furrows; fourth furrow broad and better defined posteriorly, with a shallower anterior portion that extends beyond midlength of valve, the most anterior portion curved with a downward convexity. Fifth furrow is narrow, short, close to ventral margin. A sixth furrow, not connected with posterior depressed area, parallels antero-dorsal margin, and is enlarged as a pit post-dorsally. In the four ridges separating the five, more posterior furrows, dorsalmost ridge is narrow, low; second ridge is slightly enlarged and elevated terminally; third ridge low, rather narrow; fourth ridge has a short, abruptly narrowed and hooked terminus. A narrow, low rim closely parallels anterior margin of valve.

In right valve, posterior depressed area is wanting; there are two posterior furrows, the dorsal one subparallel to post-dorsal margin, extending about two-fifths length of valve, the lower furrow about one-third length of valve, markedly divergent from ventral margin. A third furrow parallels antero-dorsal margin, and is not confluent with a dorso-median pit. Below pit in right valve of holotype shell, slightly above and anterior to midpoint of valve, is a round, very shallow depression that evidently reflects adductor scar.

The holotype shell measures length 0.7 mm., height 0.5 mm.

Relationships.—The right valve of *Thlipsuropsis diploglyptulis* closely resembles that of *T. longisulcata*, but the post-ventral furrow is distinctly shorter. The left valve differs from the holotype valve of *T. digitata* in the enlarged pit of the antero-dorsal furrow, the terminal elevation and enlargement of the ridge separating the second and third posterior furrows, and the shortness and hooked character of the terminus of the ridge separating the fourth and fifth furrows.

Occurrence.—Rare 2 to 5 feet below top of Manlius limestone, Austin's Glen, New York. A poorly preserved valve that may belong to the species was found in beds 7 to 9 feet below top of the Manlius limestone at the William Nearpass quarries, New Jersey.

THLIPSUROPSIS LONGISULCATA Swartz & Whitmore, n. sp.
Pl. 110, fig. 14,15

Left valve and hence full outline of shell not known. Right valve reniform in outline; dorsal margin moderately and rather regularly convex; posterior margin blunt; anterior margin more rounded but fuller below than above; ventral margin gently sinuate.

Surface of right valve moderately convex, rising rather steeply, especially at posterior end, from a narrow, flattened marginal flange. Surface of right valve trisulcate: two posterior furrows are sublongitudinal in direction, more or less closed posteriorly; post-dorsal furrow roughly parallels post-dorsal margin of valve; its anterior end does not quite reach midlength of valve; post-ventral furrow is about parallel to post-dorsal furrow, somewhat divergent from ventral margin of valve; its slightly down-curved end extends slightly anterior to midlength. Anterior furrow is narrower but about equal in length to posterior furrows, and parallels anterior margin; its dorsal end is closed, and does not reach a pit-like depression impressed in dorsal slope of valve slightly anterior to midlength.

The larger syntype right valve measures length 0.6 mm., height 0.4 mm.

Relationships.—The right valves of *Thlipsuropsis longisulcatus* closely resemble those of *T. diploglyptulis*, but the post-ventral furrow is decidedly longer, and the anterior furrow tends to be less oblique to the ventral margin of the valve.

Occurrence.—Rare in loose slabs of Decker limestone found in pit on Dalton Nearpass farm at the southeastern foot of Wallpack Ridge, New Jersey, in association with *Stenocisma deckerensis* and *Limbinaria bi-angulata*.

THLIPSUROPSIS DIGITATA Swartz & Whitmore, n. sp.
Pl. 110, fig. 16

Shell as known from a single, well preserved left valve, ovoid subreniform in side view; dorsal margin strongly convex, fuller posteriorly than anteriorly; posterior margin higher and more broadly rounded than anterior; ventral margin nearly straight for about half length of valve. Greatest height

slightly post-median, about five-eighths of length. Hingement and overlap not observed.

Surface of left valve rather strongly convex, its greatest convexity about one-third distance from posterior margin. A comparatively depressed but nevertheless convex area borders posterior margin, and from it five furrows extend anteriorward across posterior half of valve. Two simple, narrow furrows on dorsal slope curve parallel to dorsal margin; upper furrow extends slightly beyond midlength of valve, second furrow is shorter; third furrow is broader, more rapidly curved, sickle-shaped, terminates at midlength of valve; fourth furrow well defined, diverges anteriorly from ventral margin of valve, extends beyond midlength where it is peculiarly curved, probably margining ventral side of area of adductor attachment; fifth furrow narrow, simple, short, lying close to ventral margin. In anterior half of valve a sixth furrow roughly parallels antero-dorsal margin, is hooked at its more ventral end, slightly widened near its more posterior end. A narrow flange is set off along part of anterior margin. Of four ridges separating posterior furrows, most dorsal ridge is narrow, simple; second ridge narrows rapidly from broad, distal portion, its curving posterior end having a low extension that continues across part of floor of depressed area; third ridge is broadened medially, narrowed terminally; fourth ridge has a sharply narrowed, elongate terminus.

Floors of the two larger, medio-posterior furrows are very minutely punctate-reticulate, and there is a suggestion of still more minute punctation on more elevated parts of valve surface.

The holotype left valve measures length 0.8 mm., height 0.5 mm.

Relationships.—The sculpturing of the left valve of *Thlipsuropsis digitata* is very similar to that of *T. diploglyptulis* and warrants the supposition that the species will similarly have the contrastingly ornamented valves that characterize the genus.

Superimposed on the similarities of the left valves of *T. digitata* and *T. diploglyptulis* are a series of small differences that appear to warrant specific separation, especially in view of the difference in stratigraphic occurrence. Additional specimens of *T. digitata* will be needed to show which of the differences in ornament are most persistent. As compared to *T. diploglyptulis*, the holotype left valve of *T. digitata* is more ovoid in shape; the anterior sulcus is more elongate and ventrally hooked, and lacks the definitely widened and rounded pit near the dorsal end; in the ridges separating the posterior furrows, the second ridge is a ventrally curving, low extension, whereas that of *T. diploglyptulis* is more elevated and has a slightly enlarged terminus; the third ridge is broad; the fourth ridge has an elongate narrow terminus, as compared to the shorter, hooked terminus found in *T. diploglyptulis*.

Occurrence.—One specimen in upper part of Lower Devonian Coeymans limestone, quarries on Dalton Nearpass farm, New Jersey.

Family HEALDIIDAE Harlton
Genus PARAHEALDIA Coryell & Cuskley
PARAHEALDIA? CONVEXORIS Swartz & Whitmore, n. sp.
Pl. 110, fig. 17–19

Shell minute; outline subreniform; dorsal margin rather strongly convex, ventral margin about straight for more than half of length of shell; ends rounded, subequal. Height is about two-thirds of length. Hingement and overlap not observed.

Surface of valve moderately convex. A median sulcus, broadest above, and located slightly anterior to midlength, extends between points about one-fifth and one-half distance below dorsal margin. Two small, posteriorwardly directed spinelets occur at summit of slope rising from posterior margin; one of spinelets is near dorsal and one near ventral margin of valve.

The largest of three syntype valves measures length 0.6 mm., height 0.4 mm.

Relationships.—*Parahealdia? convexoris* differs from the genotype, *P. pecorella*, Coryell & Cuskley, 1934, in the convexity of the dorsal margin, and in this respect recalls *P.? centralis* Swartz, 1936. In the latter species, there is a submedian, rounded pit rather than a vertically elongated sulcus as in *P.? convexoris*.

Although *Parahealdia? convexoris* is here listed under the family Healdiidae, the median sulcus, subterminal spines and sub-

reniform outline give it an aspect suggestive of some members of the Thlipsuridae.

Occurrence.—Rare 7 to 9 feet below top of Manlius limestone, William Nearpass quarries, New Jersey.

APPENDIX

BRACHIOPODA

Genus CHONETES Fischer

CHONETES JERSEYENSIS var. NONDIVERGENS Swartz, n. var.

Choenetes jerseyensis WELLER (part), 1903, Geol. Survey New Jersey, Paleont., vol. 3, p. 230–231, pl. 20, fig. 16, not fig. 12,15; status of immature specimens shown in fig. 11,13,14 is uncertain.

Shell subrectangular in outline; length about two-thirds of width; cardinal angles not extended; anterior margin gently convex, bending more rapidly into the gently convex lateral margins. Pedicle valve depressed convex; cardinal area low, beak not prominent; each cardinal slope bears 6 or 7 small, obliquely directed spines. Brachial valve about flat. Surface marked by fairly coarse radial costellae, which increase by implantation and bifurcation and number 8 or 9 in 5 mm. near anterior margin. In adult as well as immature specimens, lateral costellae are about straight, and do not diverge appreciably from cardinal margins.

Length of holotype ventral valve 13 mm., width 19 mm.

Relationships.—In describing *Chonetes jerseyensis* in 1903, Weller called attention to the anterior curvature of the lateral costellae that is a very distinctive feature of many characteristic large valves of the species, but concluded that there is continuous variation into associated, generally smaller valves in which there is little if any such curvature. The anterior curvature of the lateral costellae, and an associated divergence of the postlateral costellae from the hinge, are striking and useful features of most specimens of *Chonetes jerseyensis* of the lower half of the Keyser limestone of central Pennsylvania, Maryland and the Virginias. At some localities in eastern Pennsylvania, however, such as at a small quarry on the road from Schuylkill Haven to Adamsdale (see Swartz, F. M., 1941, in Swartz, C. K., and Swartz, F. M., Early Devonian and Late Silurian formations of southeastern Pennsylvania, Geol. Soc. Am. Bull., vol. 52, p. 1134), there are assemblages in which there is an abundance of specimens with essentially straight postlateral ribs which are not appreciably divergent from the cardinal margin, and in which there are few if any valves with divergent post-lateral ribs. It accordingly seems desirable to call attention to the structural differences by use of the term, *nondivergens*, and to emphasize the possibility that the material with the non-divergent postlateral costellae may be developed chiefly in the earlier occurrences of *Chonetes jerseyensis* as a whole.

The specimen shown by Weller (1903) in his pl. 20, fig. 16, is proposed as the holotype of the variety, *C. j.* var. *nondivergens;* the smaller specimens shown in fig. 11,13 and 14 are immature valves so that their relation to the variety is less clear. It is further proposed that the valves shown in fig. 12 and 15 of the same plate should be regarded as the synlectotypes of *Chonetes jerseyensis.*

Occurrence.—William Nearpass quarries, New Jersey, lower 2 feet of Decker limestone. Quarry on road from Schuylkill Haven to Adamsdale, Pennsylvania, 12 to 16 feet below unconformity at top of Keyser limestone.

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MANUSCRIPT RECEIVED June 3, 1955.
Contribution 55-18
College of Mineral Industries
The Pennsylvania State University

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1092–1142, PL. 111–119, 8 TEXT-FIG., SEPTEMBER 1956

OSTRACODA FROM THE WINDOM SHALE (HAMILTON) OF WESTERN NEW YORK[1]

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ABSTRACT—A large and varied ostracode faunule was recovered from the Windom shale member of the Moscow formation (Middle Devonian) in western New York. The assemblage consists of 73 species and one variety, distributed among 48 genera. Seven genera, 31 species and one variety are proposed as new. The new taxa are described, discussed and illustrated. They include (*indicates type species): *Hollinella ampulla, H. epakra, H. retusilobata, H. sella, Falsipollex simplilobatus, Adelphobolbina medialis* (type species, *Ctenobolbina papillosa* Ulrich), *Subligaculum aculeatum, Richina selenicristata, Ulrichia ventura, Jonesina apoglypha, Birdsallella catena, Punctomosea* (type species, *Thrallella cristata* Swartz & Oriel), *Sulcella emicatusa, Menoeidina multipunctata, M. versicula, Strepulites divectus, Octonaria bifurcata, Bythocypris phaseoella, B. transptyxis, B. transptyxis* var. *truncata, B. tubercula, Scalptina incuda*, Prosopeionum plexum*, *Euglyphella asapha, E. deltella, Paraparchites asymmetricus, Kirkbyella tora, Amphisella papillosa*, Doraclatum compandium*, *Bideirella reticulata*, Chironiptrum? arcuatum, Roundyella? concentrica* and *Cryptophyllus arsinius*. It is also proposed to raise the subgenus *Hanaites* Pokorný to generic rank in the Hollinidae. In addition to the new genera and species listed above, two ostracodes, genus and species undet., are described and illustrated.

A comparison of the Windom Ostracoda with assemblages from other Hamilton and Mississippian formations indicates that this assemblage has its greatest affinities with older Devonian faunules, especially those from the Ludlowville formation and its equivalents, but also contains certain elements signifying trends toward younger Mississippian collections.

INTRODUCTION

IN PREVIOUS studies of the fossils from the Moscow formation in New York, little consideration was given to the microfauna. Of the micro-organisms, the most important group is the Ostracoda. This paper describes a rich and varied assemblage of Ostracoda collected from the Windom member of the Moscow formation in Western New York between Lake Erie and the Genesee Valley.

Acknowledgments.—The author wishes to express his appreciation to Dr. William R. Evitt of the University of Rochester for his constant keen interest in this work, and for his valuable aid, advice and criticism during all phases of the preparation of this paper. The writer also wishes to thank Dr. Robert V. Kesling of the University of Michigan who gave generously of his time to examine the fossils, discuss with the author various problems, and make several helpful suggestions. Appreciation is also extended to Dr. Jean M. Berdan of the U. S. Geological Survey for her pertinent comments on several problematical species; to Mr. K. Norman Sachs for assisting the writer with the photography and for making available his own collection of ostracodes; and to the Department of Micropaleontology of the American Museum of Natural History, for permission to examine the type specimens in the Coryell and Malkin collection.

This work was made possible by the Elon Huntington Hooker Fellowship of the University of Rochester Graduate School for the fiscal years 1954–55 and 1955–56. The cost of materials incurred during the photographing of the fossils and the preparation of plates and illustrations was borne by the Department of Geology, University of Rochester.

Stratigraphy.—The Moscow formation, first described by Hall (1840), constitutes the youngest formation of the Middle Devonian Hamilton group. This unit, as defined by Cooper (1930), is composed of the Windom shale above, underlain by the Kashong shale which in turn is underlain by the Menteth limestone. Sutton (1951)

[1] Part of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School, University of Rochester. Published with the permission of the Graduate School.

included in the Moscow formation the unique Leicester marcasite member that overlies the Windom shale. From Canandaigua Lake to Lake Erie, New York, the Moscow formation overlies the Ludlowville formation and is overlain by the Geneseo black shale.

The Windom shale is 48 feet thick in the Genesee Valley and thins to 39 feet at the south branch of Smoke Creek near the village of Windom, New York. At Eighteenmile Creek, approximately 10 miles southwest of Windom, the shale is only 15 feet thick. Due to the southerly dip of the rocks, the shales are below the water level of Lake Erie a few miles south of Eighteenmile Creek.

In the Genesee Valley the Windom member consists of fine-grained, medium to dark gray shales interrupted by numerous thin coquinoid limestone bands and lenses. The upper 2 feet of shale contains scattered ellipsoidal concretions and concretionary layers, and the shales are darker than those in the underlying part. Traced westward the shales become lighter and the thin, highly fossiliferous limestone lenses become nearly obsolete, whereas the concretions and contionary layers are more abundant. From approximately 35 miles west of the Genesee Valley to Lake Erie, the shales are relatively barren except for the lower 5 to 8 feet and the upper 5 feet.

List of localities.—

Locality 1. Eighteenmile Creek; section between Lake Shore road and 0.5 mile east of N. Y. route 5. Sample from lower 5 feet of Windom shale that contains abundant *Ambocoelia umbonata*, *Brachyspirifer audaculus* and tetracorals. Erie County, N. Y.

Locality 2. Unnamed stream that enters Lake Erie at Bayview; sample from lower 5 feet of Windom shale at 0.5 mile southeast of the New York, Chicago and St. Louis railroad tunnel. Erie County, N. Y.

Locality 3. Cazenovia Creek; 0.5 mile west of Spring Brook. Sample from upper 15 feet of dark gray Windom shale with a few scattered *Chonetes* sp., *Greenops boothi* and *Ambocoelia umbonata*. Erie County, N. Y.

Locality 4. Cayuga Creek south of Clinton road. Sample from the 5 feet of Windom shale directly below the Leicester marcasite member. Erie County, N. Y.

Locality 5. Sample from 8 feet of badly weathered upper Windom shale on a hillside along Peck Creek 0.34 mile west of Harlow road and just north of the Erie railroad tracks. Megafossils very abundant. Genesee County, N. Y.

Locality 6. Bowen Creek 1 mile north of U. S. route 20. Sample from lower 15 feet of Windom shale that contains *Ambocoelia umbonata* and *Chonetes mucronatus*. Genesee County, N. Y.

Locality 7. Small exposure 0.3 mile south of the intersection of N. Y. route 63 and Starr road. Sample from upper 10 feet of weathered Windom shale along the north bank of a pond. Megafossils extremely abundant. Genesee County, N. Y.

Locality 8. Type section of the Moscow formation along Little Beards Creek, 0.5 mile east of N. Y. route 36 and 0.75 mile north of Leicester. Sample from entire Windom member. Livingston County, N. Y.

Locality 9. Unnamed stream that crosses Lima road midway between Country Club and Elm-Welsh roads. Sample from upper 8 feet of Windom shale. Livingston County, N. Y.

Orientation and terminology.—The orientation and terminology followed in this paper are essentially those of Kesling (1951). The only new term employed is *keel*, which is used to describe a medial, commonly striated, sheet-like structure which arises from the free contact margin of either or both valves. It is generally confined to the posterior half of the carapace and is especially well developed in *Hanaites platus* (see Pl. 112, fig. 11–15). The additional terms, *lobate area* and *extralobate area* introduced by Hessland (1949) and accepted by Henningsmoen (1953) are also used.

Preservation.—The majority of the specimens are calcareous and, with very few exceptions, are exceedingly well preserved. Even the most fragile structures, such as spines, papillae, tubercles and delicate reticulations and ridges, are clearly discernible, as are the finer details of surface sculp-

ture. This is particularly true of the ostracodes recovered from localities 5, 7, 8 and 9. Most of the specimens from localities 3 and 4, where the samples were taken from rocks subjacent to marcasite-pyrite lenses, are partially or completely replaced by pyrite or marcasite. In pyritized specimens the finer details of ornamentation are generally obliterated and the general texture and surface configurations are coarsened. In general, specimens from localities 5 to 9 are better preserved than those from localities 1 to 4.

Previous work.—The only study of Middle Devonian ostracodes confined to the Windom member is that of Swartz & Oriel (1948) in which 22 species are described. More recently, Sutton (1951) listed 5 species from the Windom member. Prior to these papers several other authors, including Hall (1860, 1862), Jones (1890), Ulrich (1890), and Grabau (1898), noted the occurrence of ostracodes in the Moscow formation.

DISCUSSION

In recent years much work has been done on Ostracoda from Hamilton formations in New York, Ohio, Michigan and Ontario. The results of those investigations include papers by Van Pelt (1933), Warthin (1934), Coryell & Malkin (1936), Stewart (1936), Turner (1939), Stewart & Hendrix (1945a), Swartz & Oriel (1948), Campbell (1952), Coley (1954), Sachs (1956), Smith (1956), and most important of all, the excellent papers by Kesling and his associates (1951–1956). Practically all of these reports concern faunules of Ludlowville or Skaneateles age: the only investigations confined to assemblages of Moscow age are those of Swartz & Oriel and of Sachs. The reason for this is that in the western areas the Moscow formation and part of the upper Ludlowville formation are absent due to either non-deposition or subsequent erosion.

The ostracode assemblage of the Windom member is characterized by a large number of species and specimens of Quasillitidae, Cytherellidae, Bairdiidae, and by numerous species of Hollinidae. Generally, each species in the Hollinidae is represented by few specimens with the exception of *Ctenoloculina cicatricosa* (Warthin), *Hanaites platus* (Kesling & McMillan) and *Adelphobolbina medialis*, n. sp. The abundance of specimens and species of the Bairdiidae in the Windom member is regarded as significant, especially since that family is more characteristically represented in Upper Paleozoic assemblages. The Drepanellidae, Kloedenellidae, Thlipsuridae and Beyrichiidae, families that are usually well developed in Lower Devonian and Silurian rocks, are represented in the upper Hamilton by only a few species each. In addition, representatives of the Primitiidae, Aechminidae, Healdiidae, Glyptopleuridae and Acronotellidae are very rare. The absence of species of Barychilinidae in the Moscow of New York is surprising, because species in that family are present in rocks from Marcellus to Ludlowville age in Michigan, and are found in younger rocks as well. Another group of ostracodes of uncertain family assignment is represented by several genera and species. Except for *Amphizona*, only a few specimens of each of these species were found. The group closely resembles the Kirkbyidae, but lacks either a subcentral kirkbyan pit or prominent velate structures, or both.

A comparison of the ostracode assemblage from the Windom shale with that from the Ludlowville formation in New York (Campbell, 1952; Coley, 1954; Smith, 1956) indicates that approximately 65% of the species in the older unit are also found in the Windom member. Generically, *Welleria*, *Arcyzona*, *Rudderina*, *Treposella* and *Janetina* are apparently confined to the Ludlowville, whereas *Prosopeionum*, *Scalptina*, *Sulcella*, *Neokloedenella*, *Bideirella*, *Octonaria* and *Cryptophyllus* are found only in the overlying unit. However, *Octonaria* is present in Ludlowville equivalents in Michigan and *Cryptophyllus* is known from rocks from Silurian and Ordovician age. *Sulcella* and *Neokloedenella* have been previously reported only from Mississippian or younger rocks.

The above brief summary indicates that the ostracode faunule described in this paper is very similar to the assemblage found in the underlying Ludlowville formation. In spite of the similarity, slight, but perhaps significant, differences do exist. For example, *Aechmina*, not uncommon in the Ludlowville of New York, is known only

from a few broken pieces in the Windom; *Dizygopleura* is very rare in the Moscow formation (Sachs, 1956) and is represented by only one species, *D. alethaae* Coley. Several other genera are present in the Ludlowville and Windom, but are represented by different species. In other cases, where two species of the same genus occur in both units, one species is usually more abundant in one of them. These points are brought out by *Strepulites* and *Richina*. *Strepulites tischleri* Coley is common to abundant in the Ludlowville, but is replaced by *S. divectus*, n. sp., in the Windom: *Richina truncata* Coryell & Malkin is common in Ludlowville rocks from New York and Ontario, whereas, *R. selenicristata*, n. sp., is known only from localities in the Moscow formation. Similarly, *Menoeidina versicula*, n. sp., replaces *M. scopeli* Coley from the Ludlowville, but *M. multipunctata*, n. sp., is present in both formations. Of the seven new genera described in this paper, four of them, *Adelphobolbina*, *Amphissella*, *Doraclatum* and *Punctomosea*, are also found in the Ludlowville formation, and the other three, *Bideirella*, *Prosopeionum* and *Scalptina* were found only in samples taken from near the top of the Windom member.

When contrasted with ostracode assemblages from older Hamilton formations exclusive of New York state, the Windom faunule was found to contain nearly all of the characteristic Middle Devonian genera. This fact may be more fully appreciated by comparing the faunal list in this paper (Table 1) with that for the Norway Point formation of Michigan (Kesling & Weiss, 1953) and for the pre-Moscow Hamilton formations in northwest Ohio and southwest Ontario (Coley, 1954). The differences that do exist between older Hamilton ostracode faunules and the Windom faunule are not great. They are most easily recognized in those families 1) that have their greatest expression in Upper Silurian or Lower Devonian assemblages, which, by middle or late Hamiltonian, were greatly reduced in numbers or extinct (Thlipsuridae, Aechminidae, Beyrichiidae); 2) whose representatives occur first in Lower Devonian or Marcellus assemblages, and by Moscow time, were sufficiently successful to be recognized by several genera and species (Hollinidae, Quasillitidae); 3) that have their antecedents in middle or late Hamiltonian assemblages, but which are better developed in Upper Paleozoic faunules (Bairdiidae, Healdiidae, Kirkbyidae). These points are often expressed at the generic level; for example, *Aechminaria*, which occurs in rocks from Silurian to Ludlowville age, is absent in the Windom. *Aechmina*, reported from the Dundee limestone of Ohio, the Arkona shale of Ontario and the Bell shale and Norway Point formations of Michigan is known from only a few broken pieces in the upper Hamilton. After a long and successful history in the Silurian, the beyrichiids are represented by only *Hibbardia* and *Phlyctiscapha* in the Windom, and *Treposella*, known to occur in the Ludlowville formation, apparently does not extend into younger rocks. In like manner, the only representatives of thlipsurid ostracodes in the Windom are one species each of *Strepulites* and *Octonaria*, in contrast with the many genera found in Ulsterian assemblages and the several genera reported from the Traverse group of Michigan and Arkona shale of Ontario.

On the other hand by middle and late Hamilton time the hollinids had developed into a widely spread and diversified group of ostracodes that continued their expansion during the Mississippian. No new genera appear in the Windom faunule; however, several of the Windom species show close resemblances with older species. *Hollinella retusilobata*, n. sp., and *H. ampulla*, n. sp., are very similar to *H. labrosa* Kesling & Weiss and *H. inclinisulcata* Kesling & Weiss, respectively, from the Norway Point formation, and *Adelphobolbina medialis*, n. sp., resembles *A. papillosa* (Ulrich) from the Jeffersonville limestone at the Falls of the Ohio and *A. megalia* (Kesling & Tabor) from the Genshaw formation of Michigan. In addition, *Tetrasacculus paeneteichus*, n. sp., is reminiscent of *T. bilobus* Stewart from the Silica shale of Ohio and *T. paeneloculatus* Kesling & Weiss from the Norway Point formation. Similarly, the quasillitids are exceptionally well represented in both the middle and upper Hamilton. Most of the genera in the Windom assemblage are carryovers from older assemblages, with the exceptions of *Prosopeionum*, n. gen., and

Scalptina, n. gen., which were found only in those samples near the top of the member.

The Drepanellidae is also well represented, but the number of specimens is not nearly so abundant as in the Quasillitidae. *Ulrichia* is by far the most common genus, and, except for *U. ventura*, n. sp., the other species are known from the Arkona or Widder beds of Ontario or the Traverse group of Michigan. *Bollia*, which is very common in Lower Devonian rocks, and is generally represented by two or there species in older Hamilton units is represented by only one species in the Windom shale.

However, not all of the taxa indicate affinities with older Hamilton assemblages, for the species of the Bairdiidae, a family characteristically well represented in the Mississippian and Pennsylvanian faunules, are common in the Windom. *Bythocypris* is very abundant; of the five species that occur in the Windom member, three of them are known only from that unit. *Bairdia*, although common, is represented by only *B. summacuminata* Coryell & Malkin. Other typical Upper Paleozoic genera found in the Windom are *Birdsallella*, *Healdia*, *Paraparchites* and *Sulcella*. The new species, *Chironiptrum? arcuatum* is very suggestive of *Kirkbya*, and is probably allied with, if not ancestral to, the Kirkbyidae.

It is evident that the Moscow assemblage is more closely allied with older Hamilton faunas, but also contains elements that indicate trends toward younger Mississippian faunules as well. Very little is known of the ostracodes from Upper Devonian rocks, especially in the Great Lakes area; hence, no comparison can be made at this time.

Our understanding of Middle Devonian Ostracoda has greatly increased since the appearance of the paper by C. L. Cooper (1942) on the occurrence of Paleozoic Ostracoda. In that paper he lists 9 genera (marked * in following list) as representative of the Middle Devonian and cites 5 "firsts." A more complete list compiled from most of the references noted in the opening paragraph of this section is presented below:

Adelphobolbina
Aechmina
Amphizona
Arcyzona
Bairdia
**Barychilina*
Birdsallella
**Boursella*
Bufina
Coelonella
Chironiptrum
Ctenoloculina
**Euglyphella*
Eukloedenella
Dizygopleura
Falsipollex
**Favulella*
Glyptopleura
Hanaites
Hibbardia
**Hollina*
Hollinella
Jenningsina
Kirkbyella
Kloedenella
Menoeidina
Octonaria
Parabolbina
Parabufina
**Ponderodictya* [*Hamiltonella*]
Punctoprimitia
Phlyctiscapha
**Quasillites* [*Burlella*]
Richina
Subligaculum
Strepulites
Tetrasacculus
Treposella
Ulrichia
Xystinotus

Table 1 shows the abundance and distribution of the ostracode specimens collected from the Windom shale in western New York.

NOTE.—The illustrations on Pl. 111 to 119, inclusive, are unretouched photographs. The specimens were whitened before photographing with ammonium chloride sublimate. Where stereo-pairs are used, only the left hand element is numbered. All type specimens are housed at the New York State Museum, Albany, New York.

Since the preparation of this paper, additional samples from locality 7 were found to contain *Abditoloculina* sp., *Aechmina* sp., *Boursella trilobata?* Stewart, *Dizygopleura alethaae* Coley, *Ropolonellus papillatus* Coryell & Malkin and *Winchellatia?* sp. All of the above species are rare.

SYSTEMATIC PALEONTOLOGY

Order OSTRACODA Latreille
Superfamily BEYRICHIACEA
Family HOLLINIDAE Swartz, 1936
Genus HOLLINELLA Coryell

Type species: By original designation, *Hollinella dentata* Coryell, 1928b, p. 377-378.

HOLLINELLA SELLA, n. sp.
Pl. 111, fig. 1–6

Description of male.—Carapace large, subelliptical in lateral view. Dorsal border straight, ventral border gently curved, anterior border evenly rounded, posterior border subround with greatest extension in dorsal half. Hinge line straight, slightly depressed.

Quadrilobate; L1 lachrymoid, extending

TABLE 1—ABUNDANCE AND DISTRIBUTION OF OSTRACODE SPECIES

	Locality								
	1	2	3	4	5	6	7	8	9
Family Hollinidae									
Hollinella sella, n. sp.			R*				C	C	R
H. retusilobata, n. sp.							R	C	
H. epakra, n. sp.							R	R	
H. ampulla, n. sp.								R	
H. plauta Kesling & Tabor								R	
H. tricollina (Ulrich)	R					R		R	
Falsipollex simplilobatus, n. sp.							R		
Adelphobolbina medialis, n. sp.	C	R				R	R	C	R
Ctenoloculina cicatricosa (Warthin)	R			C			A	R	R
C. eurybathrota Kesling							R	R	
Hanaites platus (Kesling & McMillan)							R	C	R
Tetrasacculus paeneteichus, n. sp.							C	C	R
T. cf. *T. magnivelatus* Kesling							R	R	
Subligaculum laciniosum Kesling								R	
S. aculeatus, n. sp.							R	R	
Family Drepanellidae									
Richina selenicristata, n. sp.	R	R					R	C	R
Richina sp.								R	
Bollia hindei Jones	R	R					R	R	
Ulrichia ventura, n. sp.					R		R		
U. spinifera Coryell & Malkin	R				R			C	
U. acricula Kesling						R	C		R
U. fragilis Warthin					R		R		
U. illinearis Kesling					R		C	R	
Family Kloedenellidae									
Eukloedenella sp.								R	
Neokloedenella sp.								R	
Jonesina apoglypha, n. sp.							R	R	
Family Bevrichiidae									
Hibbardia lacrimosa (Swartz & Oriel)	R	R		R	R		A	C	C
Phlyctiscapha subovata Smith								C	R
Family Primitiidae									
Punctoprimitia subaequalis (Swartz & Oriel)			R	C	C	R	A	R	R
Family Acronotellidae									
Monoceratina casei Warthin							R		
Family Cytherellidae									
Birdsallella catena, n. sp.							C	R	R
B. devonica Coryell & Malkin	R	R					C	R	R
Punctomosea cristata (Swartz & Oriel)		R			C		C	R	C
Sulcella emicatusa, n. sp.								R	
Bythocyproidea cf. *B. eriens's* Stewart & Hendrix							R		
Menoeidina versicula, n. sp.		R			R		C		R
M. multipunctata, n. sp.					C		C		
Ponderodictya punctulifera (Hall)			C				C	C	R
Family Thlipsuridae									
Strepulites divectus, n. sp.							C	A	
Octonaria bifurcata, n. sp.							A	R	R
Family Bairdiidae									
Bairdia summacuminata Coryell & Malkin							C	A	
Bythocypris lucasensis Stewart			R		R	R	A	R	R
B. subquadrata Stewart					R		R	R	
B. transptyxis, n. sp.							C	A	R
B. transptyxis var. *truncata*, n. var.							R	C	
B. phaseoella, n. sp.							C	A	R
B. tubercula, n. sp.							C		
Family Healdiidae									
Healdia cf. *H. arkonensis* Coryell & Malkin	R						R	C	
Family Quasillitidae									
Jenningsina catenulata (Van Pelt)			R	R			A	A	C
Scaptina incuda, n. sp.							C		

TABLE 1—(*Continued*)

	Locality								
	1	2	3	4	5	6	7	8	9
Quasillites subobliquus Swartz & Oriel	R	R	R	C	C	A	R	A	
Q. angulatus Smith	A	R		R	A	R	A	A	C
Quasillites sp.				R	R				
Prosopeionum plexum, n. sp.							C	R	R
Bufina bicornuta (Ulrich)	C	C		C	C	C	A	A	C
Parabufina subovalis (Swartz & Oriel)	C	C			R		A	C	R
P. convexa Smith	C	C	R	R	C	R	C	C	R
? *Lucasella spinulifera* Stewart							R		
Euglyphella asapha, n. sp.							R	C	
E. deltella, n. sp.		R					A	A	C
E. numismoides Swartz & Oriel	A	C		C	C	C	A	A	C
Family Leperditellidae									
Coelonella scapha Stewart				R		R	C	C	R
Paraparchites asymmetrica, n. sp.							R	C	
Paraschmidtella paralobata (Swartz & Oriel)							R	R	
Family incertae sedis									
Kirkbyella tora, n. sp.	C	C				R	A	A	R
K. unicornis Coryell & Malkin							R	R	
K. verticalis Coryell & Cuskley	R						R	C	
Amphissella papillosa, n. sp.							R	R	
Amphizona asceta Kesling & Copeland	R						C	C	R
Chironiptrum? arcuatum, n. sp.								R	
Doraclatum compandium, n. sp.							R	C	
Roundyella? concentrica, n. sp.							C		
Bideirella reticulata							C		
Tubulibairdia windomensis		R					R	C	
Cryptophyllus arsinius, n. sp.	R						C	R	R
Genus and species undetermined (A)								R	
Genus and species undetermined (B)								R	

* R = Rare, less than 10 valves per 750 g. sample.
C = Common, more than 10, but less than 25 valves per 750 g. sample.
A = Abundant, more than 25 valves per 750 g. sample.

from just below the dorsal border to the frill, in part confluent with ventral lobe, but set off from the latter by a shallow furrow. L2 very small, elliptical, elongate vertically, fullest in ventral half. L2 extends from just below the dorsal border to mid-height; anteroventral portion joins L1. L3 large, bulbose, extending from the dorsal margin or a little above it to mid-height. L4 with low relief, broad, ventrally confluent with ventral lobe. Ventral lobe large, pronounced, with greatest swelling ventral to S2. Base of ventral lobe parallel to frill.

Trisulcate; S1 shallow, short, convex anteriorly, extends from the dorsal border to one-third maximum height where L1 and L2 are confluent. S2 slightly anterior to mid-length, wide and deep, and extends from dorsal border to center of valve where it widens and continues under L2 and L3 separating them from the ventral lobe. S3 very shallow, poorly defined, extending from dorsal border to base of L3.

Frill narrow and sharply set off from the lateral surface except at the anterior corner. Frill extends from the anterior corner to the posteroventral part of the valve where it terminates in a short, blunt, spine directed outward and backward. Frill of approximately equal width throughout and flared outward along its entire length. In ventral view, the frills are nearly parallel, converging slightly anteriorly.

Channel ornamented with a single row of widely spaced tubercles on each valve and by a row of closely spaced papillae on the left valve only along the free edge of the contact margin. Rest of channel finely granulose.

Lateral surface coarsely granulose except in sulci. Posterior end with numerous marginal tubercles. Isolated tubercles pres-

ent on all lobes and especially common on ventral lobe.

Anterior cardinal angle approximately 150°; posterior cardinal angle approximately 120°.

Description of female.—General outline, lobation, sulcation and lateral ornamentation similar to that of the male. Female with wider frill, incurved anteriorly and flared outward at the posteroventral end. Frill widest at the anteroventral corner. Lobes on the female are smaller but more prominent than on the male. Channel smooth, completely unornamented.

Anterior cardinal angle approximately 125°; posterior cardinal angle approximately 110°.

Measurements.—Greatest length through S2; greatest height through L2; greatest width through L3. Dimensions of the holotype are: length, 1.63 mm.; height, 0.90 mm.; width, 0.90 mm. The average dimensions of 4 males and 4 females are given below (mm.).

	length	height	width
male	1.70	0.93	0.92
female	1.80	1.00	1.00

Remarks.—The distinguishing characteristics of *Hollinella sella*, n. sp., are its relatively large size, the small vertically elongate L2 which does not extend to the dorsal border, and the strongly tuberculated posterior margin, especially on the male. These features readily set it apart from other described species of the genus.

Occurrence.—Common at loc. 7 and 8; rare at loc. 3 and 9.

Specimens.—Holotype, a male carapace, loc. 7, NYSM 10817; paratype, a male left valve, loc. 7, NYSM 10818; allotype, a female left valve, loc. 8, NYSM 10819.

HOLLINELLA RETUSILOBATA, n. sp.
Pl. 111, fig. 7,8

Description of female.—Valve subpyriform in lateral view; dorsal border straight; anterior and posterior borders unevenly rounded, greatest extension in dorsal half; ventral border gently curved with posterior swing. Hinge line straight, about four-fifths as long as the valve.

Quadrilobate; L1 small, nodelike; little more than a swelling at the anterior border, confluent with frill. L2 large, elongate, and inclined anteroventrally. Extends from below the dorsal border to the anteroventral portion of frill; anterior side of L2 notched at approximately one-third the total length from its pointed dorsal edge. Large bulblike L3 extends from the hinge line to midheight. A small, vertically-elongate, gently-inflated L4 extends from the dorsal border to the posterocentral part of the valve. L4 more inflated ventrally than dorsally and confluent with the ventral lobe. Ventral lobe scalene, widest and most inflated immediately ventrad to S2. Base of ventral lobe arcuate, extending to the frill.

Trisulcate; S1 deep, wide and long; extends from the dorsal border to the frill. S2 vertical in the dorsal half and inclined anteroventrally in the ventral half. A short minor furrow leads posteriorly from S2 extending beneath L3, separating the latter from the ventral lobe. S3 short, shallow and arcuate; curves around and under L3.

A very wide, thick frill extends approximately three-quarters of the distance around the free border from the anterior corner, terminating posteroventrally in a well developed spur. Frill is flared outward and very wide. Channel finely granulose and ornamented by a few tubercles in the central ventral portion; a small papillated ridge is present along the free edge of the contact margin.

Lateral surface and frill finely granulose. Posterior border with marginal tubercles and a few isolated tubercles occur on the lobes.

Anterior cardinal angle approximately 125°; posterior cardinal angle approximately 115°.

Description of male.—Sulcation, lobation and ornamentation like that of female. Male subelliptical in lateral view and with larger L3 and ventral lobes. L2 is not notched. Frill of male narrower, not incurved anteriorly.

Anterior cardinal angle approximately 140°; posterior cardinal angle approximately 125°.

Measurements.—Greatest length through the base of L3; greatest height located at approximately one-third the distance from the anterior end; greatest width through ventral lobe. The dimensions of a male

right valve and the average dimensions for five female left valves are listed below (mm.).

	length	height
male	1.90	1.10
female	1.95	1.10

Remarks.—*Hollinella retusilobata*, n. sp., resembles *H. labrosa* Kesling & Weiss from the Norway Point formation of Michigan, but differs from it in lateral outline and by having a less well defined L1 and a distinctly notched L2 on the female. In the new species L3 does not extend above the dorsal border; the ventral lobe extends farther posteriorly and is more elongate than in *H. labrosa*.

Occurrence.—Common at loc. 8; rare at 7.

Specimens.—Holotype, a female left valve, loc. 8, NYSM 10820; allotype, a male right valve, loc. 8, NYSM 10821 (not illustrated).

Hollinella epakra, n. sp.
Pl. 111, fig. 9–11

Description of female.—Valves of medium size, subpyriform in lateral view. Dorsal border straight; anterior border unevenly rounded; ventral border nearly straight, almost parallel to the dorsal border; posterior end very narrowly rounded, acuminate, with definite swing in posteroventral area. Hinge line straight, approximately four-fifths as long as the valve.

Quadrilobate; L1 slightly inflated, arcuate, convex anteriorly; extends from the dorsal border to the frill and is confluent with the ventral lobe. Small nodelike L2 is located well below the hinge line and at its anteroventral edge is joined to L1. L3 large, bulbose, reaching above the hinge line. L4 comprises the gently inflated posterior one-fifth of the valve. Ventral lobe short, elongate horizontally, weakly set off from L1 and L4, and parallel to the ventral central portion of the frill.

Trisulcate; S1 short, narrow, convex anteriorly and extends from the dorsal border to just above midheight. Deep S2 extends from the dorsal border to slightly above the center of the valve where it widens and swings anteriorly and posteriorly under L2 and L3 respectively. S3 short, shallow and follows the posterior outline of L3.

Frill relatively wide, extending two thirds of the total distance around the free border from the anterior corner. Entire frill sharply set off from the lateral surface by a furrow and the ventral portion of the frill is flared outward. Channel smooth.

Lateral surface and frill finely granulose with scattered tubercles on L4 and the ventral lobe. Marginal tubercles present along the posterior border in some specimens.

Anterior cardinal angle approximately 130°; posterior cardinal angle approximately 120°.

Description of male.—Valves subelliptical

Explanation of Plate 111

Fig. *1–6*—*Hollinella sella*, n. sp. *1,2*, Left and right lateral views of male carapace, holotype, NYSM 10817. *3*, Lateral view of male left valve, paratype, NYSM 10818. *4*, Lateral view of female left valve, allotype, NYSM 10819. *5*, Ventral view of holotype. *6*, Ventral view of allotype. ×20. (p. 1096)

7,8—*Hollinella retusilobata*, n. sp. Lateral and ventral views of female left valve, holotype, NYSM 10820. ×20. (p. 1099)

9–11—*Hollinella epakra*, n. sp. *9*, Lateral view of male right valve, allotype, NYSM 10822. *10*, Lateral view of female right valve, holotype, NYSM 10823. *11*, Another female valve, paratype, NYSM 10824. ×25. (p. 1100)

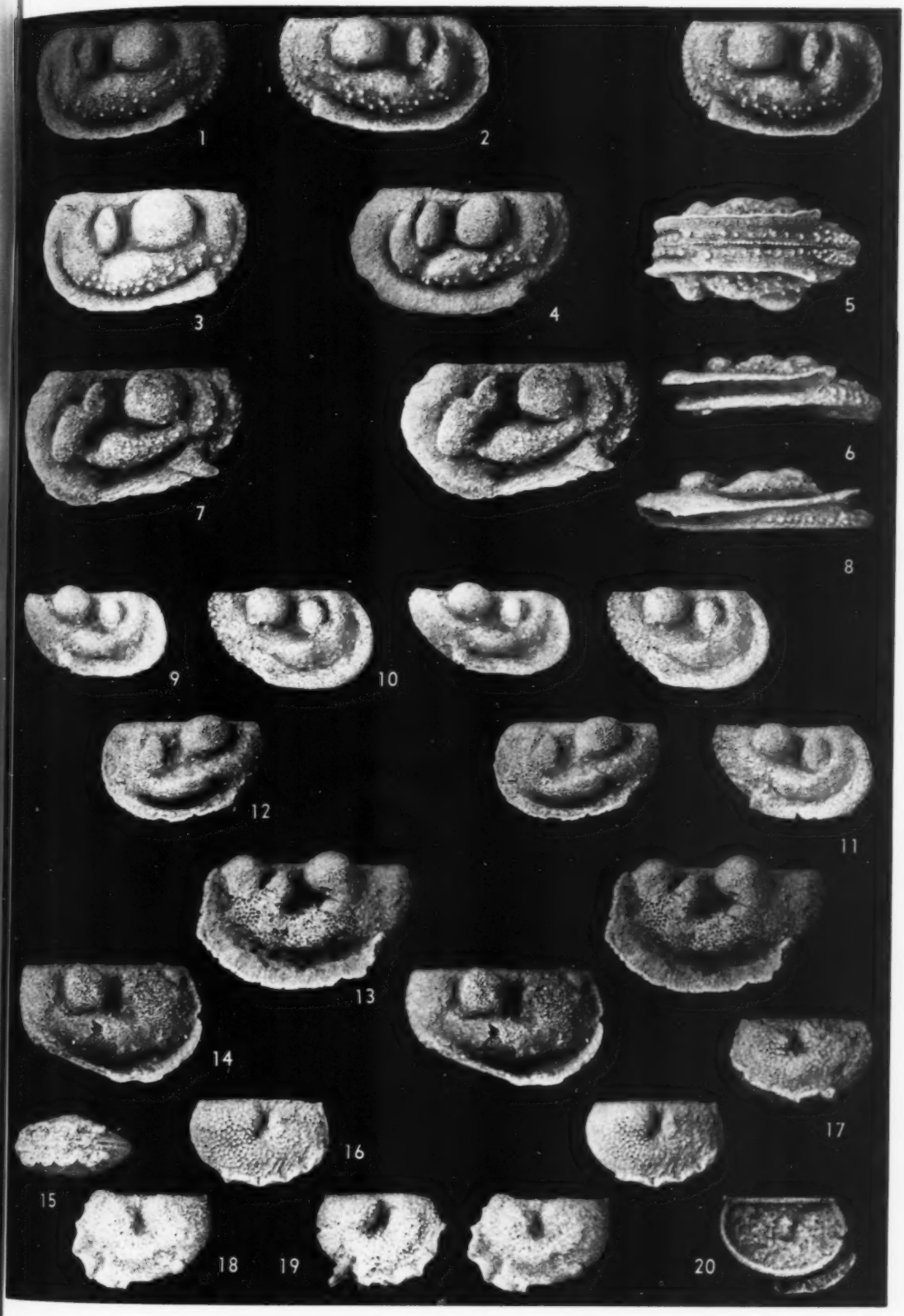
12—*Hollinella ampulla*, n.sp. Left lateral view of carapace, holotype, NYSM 10825. ×25. (p. 1101)

13—*Hollinella tricollina* (Ulrich). Lateral view of left valve, hypotype, NYSM 10827. L4 obscured by matrix and the specimen is cracked posterior to L3. ×20. (p. 1102)

14—*Hollinella plauta* Kesling & Tabor. Right lateral view of carapace, hypotype, NYSM 10828. ×25. (p. 1102)

15–17—*Subligaculum laciniosum* Kesling. Ventral, left and right lateral views of female carapace, hypotype, NYSM 10829. ×30. (p. 1108)

18–20—*Subligaculum aculeatum*, n. sp. *18*, Lateral view of female left valve, posterior chamberette broken, paratype, NYSM 10831. *19*, Right lateral view of female carapace, specimen slightly crushed along posterior border, holotype, NYSM 10830. *20*, Interior view of female left valve, paratype, NYSM 10832. ×30. (p. 1107)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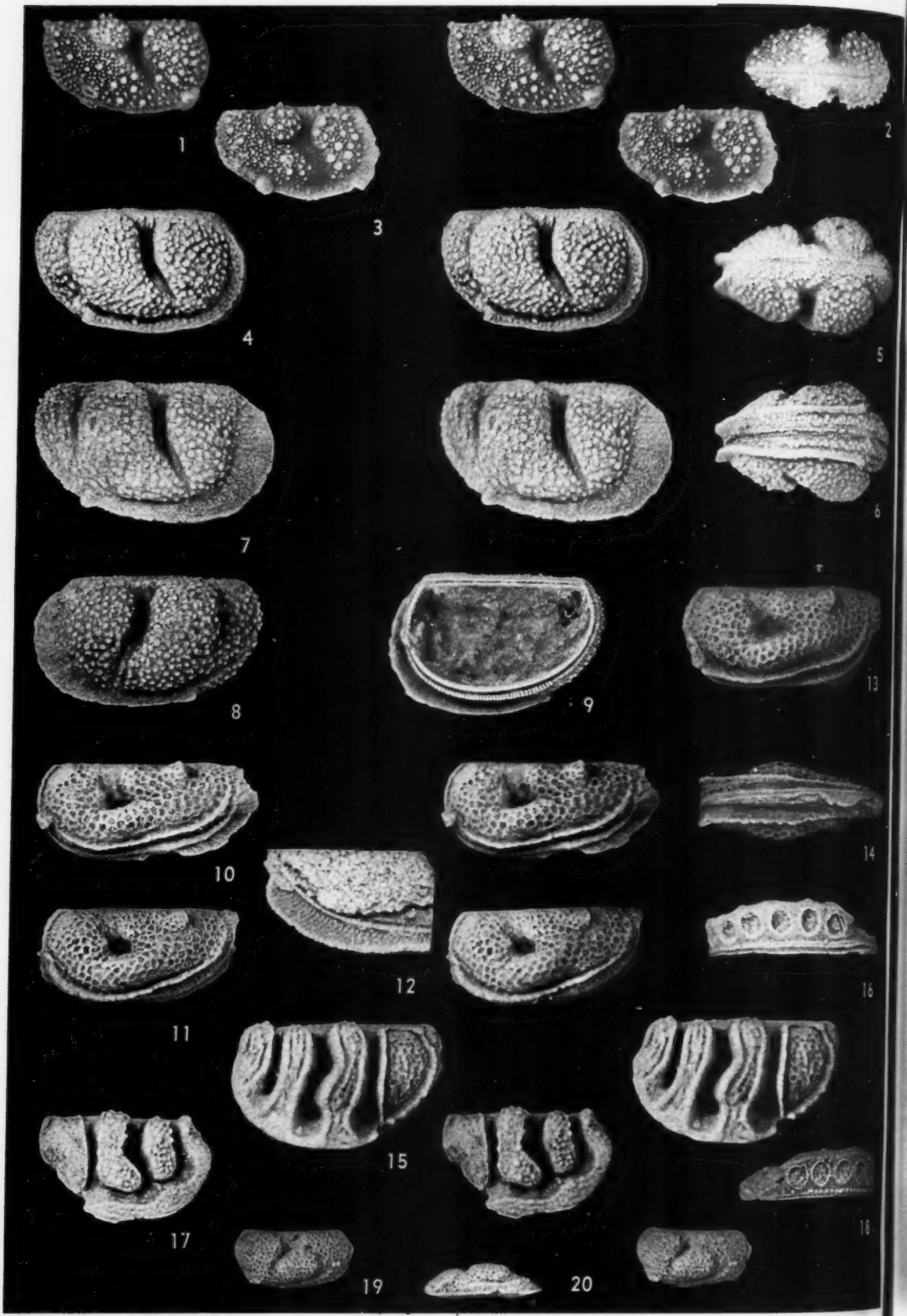
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in lateral view; less high than female. Swing sharper and the posterior end more pointed in the male. Lobation, sulcation and surface ornamentation same as those of the female.

Anterior cardinal angle approximately 145°; posterior cardinal angle approximately 130°.

Measurements.—Greatest length midway between dorsal and ventral borders; greatest height through L2; greatest width through the middle of L3. Dimensions of the holotype and allotype are (mm.):

	length	height	width of valve
allotype male	1.04	0.52	0.31
holotype female	1.04	0.54	0.35

Remarks.—*Hollinella epakra*, n. sp., is similar to *H. ampulla*, n. sp., but differs from it by having a more nearly straight ventral border, a hemispherical rather than a vertically elongate L2, a less prominent ventral lobe, and an acuminate posterior end.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Holotype, a female right valve, loc. 8, NYSM 10823; allotype, a male right valve, loc. 7, NYSM 10822; paratype, female right valve, loc. 8, NYSM 10824.

Hollinella ampulla, n. sp.
Pl. 111, fig. 12

Description of female.—Valves of medium size, subpyriform in lateral view. Dorsal border straight; anterior border evenly rounded; ventral border gently curved; posterior border broadly rounded. Hinge line straight, about seven-eighths as long as the valve.

Quadrilobate; L1 low, arcuate, convex anteriorly; extends from the dorsal border to below L2 where it merges with the ventral lobe. L2 a small vertically elongate node with a pointed dorsal edge and situated well below the dorsal border; joined to L1 in the anterocentral area. L3 a large knob, horizontally elongate and reaching above the hinge line for about one-quarter its own height. L4 gently inflated, nearly parallel to the posterior border. Ventral lobe horizontally elongate, prominent; confluent anteriorly with L1 and terminates abruptly posteriorly directly ventrad to the middle of L3. Ventral edge gently curved.

Frill extends from a little below the anterior corner approximately three-quarters of the distance around the free border, set off from the lateral surface by a shallow groove, and is flared outward along the ventral border. Channel finely granulose. Contact edge of free margin raised to form distinct ridge. Lateral surface and frill granulose.

Anterior cardinal angle approximately 120°; posterior cardinal angle approximately 110°.

Description of male.—Lateral outline, lobation, sulcation and ornamentation like

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Explanation of Plate 112

Fig. *1–3*—*Falsipollex simplilobatus*, n. sp. *1,2*, Right lateral and dorsal views of male carapace, holotype, NYSM 10833. *3*, Lateral view of female right valve, allotype, NYSM 10834. ×25. (p. 1102)

4–9—*Adelphobolbina medialis*, n. gen., n. sp. *4,5,6*, Right lateral, dorsal and ventral views of male carapace, holotype, NYSM 10835. *7*, Lateral view of female right valve, allotype, NYSM 10836. *8*, Female left valve, lateral view, paratype, NYSM 10837. *9*, Interior view of female right valve, paratype, NYSM 10838. ×20 (p. 1104)

10–14—*Hanaites platus* (Kesling & McMillan). *10*, Left lateral view of male valve, hypotype, NYSM 10840. *11*, Left lateral view of female carapace, hypotype, NYSM 10841. *12*, Interior view of keel showing striations, posteroventral area of left valve, hypotype, NYSM 10842. *13,14*, Left lateral and ventral views of female carapace, hypotype, NYSM 10843. ×25. (p. 1105)

15,16—*Ctenoloculina cicatricosa* (Warthin). Lateral and ventral views of female left valve, hypotype, NYSM 10844. ×25. (p. 1105).

17,18—*Ctenoloculina eurybathrota* Kesling. Lateral and ventral views of female right valve, hypotype, NYSM 10845. ×25. (p. 1105)

19,20—*Tetrasacculus* cf. *T. magnivelatus* Kesling & McMillan. Lateral and ventral views of left valve, hypotype, NYSM 10846. ×30. (p. 1107)

those of the female. Frill of male narrower, and the height of the male is less than that of the female.

Measurements.—Greatest length of valve through the base of L3; greatest height through the anterior part of S2; width through L3 and ventral lobe approximately equal. Dimensions of the holotype are: length, 1.10 mm.; height, 0.68 mm.; width, through L3, 0.28 mm.

Remarks.—*Hollinella ampulla*, n. sp., resembles *H. inclinisulcata* Kesling & Weiss, from the Norway Point formation of Michigan but differs from it in having a better differentiated L2, a deeper and wider S2, a more inflated ventral lobe, and a frill that begins below the anterior corner. In addition, the distance between L3 and the ventral lobe is greater in *H. ampulla*.

Occurrence.—Rare at loc. 8.

Specimens.—Holotype, a female left valve NYSM 10825; paratype, a male carapace, loc. 8, NYSM 10826 (not illustrated).

HOLLINELLA PLAUTA Kesling & Tabor
Pl. 111, fig. 14

Hollinella plauta KESLING & TABOR, 1953, p. 86–87, pl. 1, fig. 18–22.

Remarks.—The specimen from the Windom member has a less well defined L2 and lacks the low, blunt spine along the dorsal edge of L3.

Occurrence.—Rare at loc. 8.

Specimen.—Hypotype, an adult carapace, loc. 8, NYSM 10828.

HOLLINELLA TRICOLLINA (Ulrich)
Pl. 111, fig. 13

Beyrichia tricollina ULRICH, 1891, p. 189, pl. 12, fig. 6.
Hollinella tricollina WARTHIN, 1937, card 79.

Supplementary description.—Valve large, subrhomboidal in lateral view. Dorsal border straight, ventral border curved; anterior border evenly rounded; posterior border broadly rounded, greatest extension a little below the dorsal border. Hinge line straight, about five-sixths as long as the valve.

Quadrilobate; L1 prominent, hemispherical, extending above the hinge line at the anterior corner. L2 small, subtriangular with apex well below the dorsal margin. Large knob-like L3 extends from above the hinge line to about one-third the distance to the ventral border. L4 gently arched comprising posterior one-fifth of valve and confluent with ventral lobe and L3 posteroventrally. Ventral lobe small, elongate horizontally and confined to posterior half of valve, most inflated posteriorly; separated from L1 by a small saddle directly below S2.

Trisulcate; S1 short, straight and narrow, directed downward and forward from the dorsal border. A wide and deep S2 extends vertically from the hinge line, widens in its ventral half, and clearly sets off the posterior edge of L2. Posterior part of S2 curved under L3 separating it from the ventral lobe. S3 barely more than a shallow groove parallel to the posterior edge of L3.

Frill wide and delicate; faintly striated; extends from a little below the anterior corner to the posteroventral part of valve, gently flared throughout and set off from the rest of the lateral surface. Lateral surface granulose except sulci and frill. Channel smooth and very narrow.

Measurements.—Greatest length through the base of L3; greatest height and width through the center of L3. Dimensions of a left valve are: length, 1.78 mm.; height, 1.10 mm.; width, 0.45 mm.

Remarks.—Warthin (1937) believed that the major sulcus extended all the way to the base of the frill. Although a slight depression does occur immediately ventrad to S2, the writer does not consider this an extension of the sulcus, because of the striking difference in depth. Rather, the shallow saddle serves as a minor division marker setting off the ventral lobe from the anterocentral part of the valve. No dimorphism was noted in the available specimens.

Occurrence.—Rare at loc. 1, 6 and 8.

Specimens.—Hypotype, a left valve, NYSM 10827, loc. 8.

Genus FALSIPOLLEX Kesling & McMillan

Type species: By original designation, *Falsipollex altituberculatus* Kesling & McMillan, 1951, p. 68–69, pl. 3, fig. 1–3.

FALSIPOLLEX SIMPLILOBATUS, n. sp.
Pl. 112, fig. 1–3

Description of female.—Carapace of medium size, subpyriform in lateral view, pan-

duriform in dorsal view. Left valve slightly larger than right valve. Dorsal border straight, ventral border gently curved; anterior border evenly rounded; posterior border blunt, straight to subrounded with moderate posteroventral swing. Hinge line straight, approximately four-fifths as long as the valve. Anterior lobe large, L1 and L2 undifferentiated, extends from the dorsal border to the frill, and sharply set off from the frill. L3 relatively small, hemispherical, and extending slightly above the hinge line. L4 weakly developed, little more than a low swelling posterior to L3; merges with gently inflated area immediately ventrad to L3.

Bisulcate; S2 deep, extends vertically from the dorsal border to the center of the valve; a shallower part continues anteroventrally almost to the frill. Another still narrower segment, tapering posteriorly, swings under L3 and joins S3. S3 short, convex posteriorly and sharing in the demarkation of L3.

A relatively wide frill extends from the anterior corner approximately three-fourths of the distance around the free border and terminates in a thick, blunt spur. Frill flared outward, slightly wider in the anteroventral area, set off from the lateral surface by a shallow furrow and finely granulose. Channel smooth, unornamented. Free edge of contact margin raised to form rounded median ridge.

Lateral surface, except for sulci, papillose and studded with numerous, distinct, high, rounded tubercles, especially on L3 and the anterior lobe.

Anterior cardinal angle approximately 115°; posterior cardinal angle approximately 120°.

Description of male.—Posterior border of male very broadly rounded, nearly straight in the dorsal half; posteroventral swing less than in the female. Lobation like that of the female, but S2 is shorter, extending from the dorsal border about two-thirds of the distance toward the ventral border. Male has a second, smooth, well developed spur instead of a frill on each valve. In addition, the free edge of the contact margin in the male is ornamented with a fine, bead-like row of papillae and a small spine at the posterior corner is directed outward and upward.

Anterior cardinal angle approximately 115°; posterior cardinal angle approximately 100°.

Measurements.—Greatest length midway between dorsal and ventral borders; greatest height through S2; greatest width through the middle of L3. Dimensions of the holotype and allotype are (mm.):

	length	height	width
holotype	1.30	0.78	0.31
allotype	1.26	0.73	0.62

Remarks.—*Falsipollex simplilobatus*, n. sp., is easily separated from the previously described species of *Falsipollex* by its simple lobation in both sexes, and by the frill in the female, which has an ornamentation strikingly different from that on the lateral surface. In other species, the frill has the same ornamentation as the rest of the valve.

Occurrence.—Rare at loc. 7.

Specimens.—Allotype, a female left valve, NYSM 10834; holotype, a male carapace, NYSM 10833; paratype, a female left valve; all types from loc. 7.

Genus ADELPHOBOLBINA, n. gen.

Type species: *Ctenobolbina papillosa* Ulrich, 1891, p. 186, pl. 15. fig. 8a–e.

Description.—Carapace large, subrhomboidal to subovate in lateral view. Dorsal border straight. Hinge line straight, approximately three-fourths as long as the valve. Left valve generally larger than right.

Trilobate; L1 and L3 large and make up about three-fourths of the lateral surface from the anterior end. L4 weekly developed in most species. Ventral lobe, when present confluent with L1 and L3.

Bisulcate; S2 prominent, situated a little anterior of center, at least one-half as high as the valve exclusive of the frill. S3 generally poorly developed, arcuate in most species. Frill restricted, extends from the anterior corner to the posteroventral region, commonly terminated posteroventrally by a spur. Channel smooth or ornamented.

Lateral surface granulose or papillose and usually ornamented with scattered tubercles or short, blunt spines.

Dimorphic; the frill of the female is generally wider than the frill of the male, and is commonly incurved in the anterior region. In most species the channel of the female is unornamented.

Remarks.—This genus is erected to include several Devonian species which were assigned to *Ctenobolbina*. These include: *Ctenobolbina papillosa*, Ulrich, 1891, from the Jeffersonville limestone at the Falls of the Ohio River; *Ctenobolbina trilobata* Stewart, 1936, from Silica shale of Ohio; *Ctenobolbina spicata* Kesling & McMillan, 1951, from the Bell shale of Michigan; *Ctenobolbina megalia* Kesling & Tabor, 1952, from the Genshaw formation of Michigan; *Ctenobolbina papillata* (Tolmachoff) and *Ctenobolbina bulbosa* (Tolmachoff) 1898–1902, both species from Ellesmere Island, Arctic America. (See Warthin, 1937, cards 66 and 67.) *Ctenobolbina pinguis* Kesling & McMillan, 1951, should be included if it is not a synonym of *C. trilobata* Stewart.

These species differ from the type species of *Ctenobolbina*, *C. ciliata* (Emmons), in having a restricted frill, S2 and S3 of unequal length with S2 nearer the center of the valve, and a larger, bulb-like central lobe. In addition, none of the Devonian species has a central ventral spine.

ADELPHOBOLBINA MEDIALIS, n. sp.
Pl. 112, fig. 4–9

Ctenobolbina papillosa CORYELL & MALKIN, 1936, p. 3, fig. 6.

Description of male.—Carapace large, subrhomboidal in lateral view, panduriform in dorsal view, circular in anterior and posterior view. Dorsal border straight; ventral border gently curved; anterior border evenly rounded; posterior border unevenly rounded, greatest extension at one-fourth the maximum height below the dorsal border.

Trilobate; L1 gently rounded in ventral half, fullest near the major sulcus. L3 strongly inflated with comma-like shape. Bulbose dorsal portion extends to or slightly above the dorsal border. L4 forms posterior one-eighth of valve; only slightly inflated, confluent ventrally with L3.

Bisulcate; S2 long, extending from the dorsal border almost to the frill with geniculum at midheight. Dorsal portion of S2 wide, deep and slanted slightly anteriorly. Ventral portion below the geniculum shallower and narrower than the dorsal portion but more inclined anteroventrally. S2 widest at the dorsal border, deepest at midheight. S3 short, shallow and convex posteriorly; extends from a little below the dorsal border to midheight.

Frill narrow, widest at the anteroventral corner, flared outward and terminating posteroventrally in a very short spur pointed outward and backward. The frill extends from a little below the anterior corner approximately two-thirds of the distance around the free border. Surface of frill finely granulose. In ventral view, the frills are nonparallel, converging gradually anteriorly. Channel ornamented with numerous tubercles in central ventral area only. Left valve with bead-like row of papillae along the ventral and anterior free edge of the contact margin. Lateral surface coarsely tuberculate, except in the sulci.

Anterior cardinal angle approximately 135°; posterior cardinal angle approximately 120°.

Description of female.—Outline, sulcation, lobation and surface ornamentation like that of the male. The female is slightly larger than the male and has a wider frill which is incurved along the anterior border, flared outward along ventral border and terminated posteroventrally with a more pronounced spur than in the male. In ventral view, the frills are parallel and the channel is smooth and unornamented throughout.

Anterior cardinal angle approximately 140°; posterior cardinal angle approximately 130°.

Measurements.—Greatest length midway between the dorsal and ventral borders; greatest height through or a little to either side of S2; greatest width through the center of L3. Dimensions of typical adult specimens are (mm):

	length	height	width
male	1.70	1.00	0.95
female	1.80	1.10	1.05

Remarks.—*Adelphobolbina medialis*, n. sp., resembles *A. papillosa* (Ulrich), but differs from it by having a longer S3 with a geniculum, and a shorter frill which terminates in a spur. This new species can be differentiated from *A. megalia* (Kesling & Tabor) by its long, curved S3 and its evenly tuberculate surface.

Occurrence.—Common at loc. 1 and 8; rare at loc. 2, 6, 7 and 9.

Specimens.—Holotype, a male carapace, NYSM 10835; allotype, a female right valve, NYSM 10836; paratypes, a female left valve, NYSM 10837, a female right valve, 10838. All from loc. 8. A female carapace, paratype, NYSM 10839, loc. 1 (not figured).

Genus CTENOLOCULINA Bassler

Type species: *Tetradella cicatricosa* Warthin, 1934, p. 209, pl. 1, fig. 4-6, by original designation of Bassler, 1941, p. 22–23.

CTENOLOCULINA CICATRICOSA (Warthin)
Pl. 112, fig. 15,16

Tetradella cicatricosa WARTHIN, 1934, p. 209, pl. 1, fig. 4–6.
Ctenoloculina cicatricosa BASSLER, 1941, p. 22–23.
Ctenoloculina acanthophora SWARTZ & ORIEL, 1948, p. 553, pl. 79, fig. 8–14.
Ctenoloculina cicatricosa KESLING, 1952a, p. 247–290, pl. 1–3.
Ctenoloculina cf. *C. cicatricosa*, PŘIBYL, 1953, p. 92, pl. 7, fig. 1–3.
Ctenoloculina cicatricosa KESLING & WEISS, 1953, p. 44, pl. 2, fig. 9–14 and pl. 3, fig. 1. [For a complete synonymy consult this paper.]

Remarks.—A narrow, thin, faintly striated keel, similar to the median structure on *Hanaites platus*, is present on some specimens of *Ctenoloculina cicatricosa*. The keel apparently arises from both valves and extends from the posterior termination of the frill to the posterior corner. Generally this thin strip of shell material is broken and only fragmentary pieces attest to its presence. Because no adult male specimens were found, its occurrence on the male is not known.

Occurrence.—Abundant at loc. 7; common at loc. 4, and rare at loc. 1, 8, and 9.

Specimens.—Hypotype, an adult female left valve, NYSM 10844, loc. 7. Unfigured specimens; a left and right valve, female, Loc. 7.

CTENOLOCULINA EURYBATHROTA Kesling
Pl. 112, fig. 17,18

Ctenoloculina eurybathrota KESLING, 1952c, p. 46–48, pl. 1, fig. 1–9.
Ctenoloculina eurybathrota KESLING & TABOR, 1953, p. 94, pl. 1, fig. 1,2.
Ctenoloculina eurybathrota KESLING, 1953b, p. 207–208, pl. 2, fig. 17,18.

Remarks.—Only females of this species were found. The specimens have a small ridge, ornamented with triangular papillae, at the free edge of the contact border parallel to the frill.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Hypotype, a female right valve, loc. 7, NYSM 10845. Unfigured specimen, a female right valve, loc. 8.

Genus HANAITES Pokorný

Type species: By original designation, *Halliella* (*Hanaites*) *givetiana* Pokorný, 1950, p. 87, pl. 2, fig. 5; pl. 5, fig. 12,13.

In 1950, Pokorný included *Halliella* Ulrich in the Hollinidae and referred *Hanaites* to *Halliella* as a subgenus. However, several considerations seem to refute this assignment; species assigned to *Halliella* do not show dimorphism and lack velate structures. These features are generally associated with the Hollinidae. On the other hand, the velate structures, lobation and sulcation in *Hanaites* are comparable to like features in most of the hollinids. In addition, *Hanaites* shows typical hollinid dimorphism. For remarks on dimorphism in the Hollinidae see Kesling, 1952b.

It is proposed that: (1) *Hanaites* be removed from the genus *Halliella* and (2) *Hanaites* be raised to generic rank in the Hollinidae.

HANAITES PLATUS (Kesling & McMillan)
Pl. 112, fig. 10–14

Proplectrum platum KESLING & MCMILLAN, 1951, p. 64–65, pl. 1, fig. 1,2.

Description of female.—Carapace subtriangular to subrectangular in lateral view. Dorsal border straight; anterior border evenly rounded; ventral border straight, nearly parallel to the dorsal border; posterior border gently inclined forward. Hinge line straight. Left valve slightly larger than right.

L1 gently inflated, best developed in the anterocentral part of the valve. L1 and ventral lobe confluent. Ventral lobe elongate vertically, strongly inflated and situated directly below the deep pit-like termination of S2. L3 small, circular, little more than a swelling directly below the hinge line and posterior to S2. Major sulcus extends from the dorsal border to the center of the valve and is directed slightly posteriorly.

Narrow, outwardly-flared frill extends from central anterior area to below the

ventral lobe, then narrows to become a velate ridge paralleling the contact margin and continuing posteriorly to or slightly ventrad of the posterodorsal corner. A striated keel extends around the free border from below S2 to the posterior corner. At the latter, the shell material thickens and may be the root of a posterior spine.

Surface coarsely reticulate; a small conical node is situated in the posterodorsal part of valve just below the hinge line. The anterodorsal area tends to be free of reticulations.

Supplementary description of male.—General outline, lobation and sulcation like that of female. Velate ridge extends from posterior corner to central anterior area ending in a spur. Keel as in the female.

Measurements.—Greatest length including the keel through the base of S2; greatest height slightly anterior to S2; greatest width through the middle of the ventral lobe. Dimensions of a male left valve and a typical adult female carapace (excluding the keel) are (mm.):

	length	height	width
male left valve	1.26	0.64	0.28
female carapace	1.35	0.65	0.55

Remarks.—The palmate spur of the male, described and illustrated by Kesling and McMillan from specimens found in the Bell shale of Michigan was not observed, but some specimens show a suggestion of widening at the anterior end of the broken spur. The finding of the female makes possible completion of the description of this interesting ostracode, and confirms the suspicions of Kesling and McMillan that this species is dimorphic.

Occurrence.—Common at loc. 8; rare at loc. 7 and 9.

Specimens.—Hypotypes, male left valve, NYSM 10840, loc. 9; two female carapaces, NYSM 10841, 10843, and a fragment of a left valve, NYSM 10842, loc. 8. Unfigured specimen, immature male carapace, loc. 8.

Genus TETRASACCULUS Stewart

Type species: By original designation, *Tetrasacculus bilobus* Stewart, 1936, p. 744–745, pl. 100, fig. 8–11.

TETRASACCULUS PAENETEICHUS, n. sp.
Pl. 113, fig. 1–6

Description of female.—Carapace small, subpyriform in lateral view; subpanduriform in dorsal view; subtriangular in anterior view. Anterior border evenly rounded; posterior border surbrounded, acuminate in dorsal half; dorsal border straight; ventral border gently rounded. Left valve inconspicuously larger than right. Hinge line straight, approximately seven-eighths as long as the valve.

Bilobate; both lobes confluent with frill. Anterior lobe gently inflated, best developed adjacent to the major sulcus. Posterior lobe strongest ventrally with steep posterior slope.

Unisulcate; S2 anterior to midlength, extends vertically from a little below the hinge line to the center of the valve, then continues downward and forward to the edge of the frill. S2 widest and deepest in dorsal half. Geniculum slightly dorsal to midheight.

Frill gently scalloped with indentations corresponding to the positions of the partitions between the loculi. Frill with five loculi—anterior four complete, posterior loculus incomplete. A slightly recessed horizontal septum separates the incomplete loculus from the adjacent one. Anterior three loculi surrounded by distinct circular rims. All loculi separated from the free edge by a finely pitted channel. The edge of the free contact margin is raised to form a low, rounded, median ridge. Lateral surface finely reticulated.

Anterior cardinal angle approximately 115°; posterior cardinal angle approximately 125°.

Description of male.—General outline, sulcation, lobation and surface ornamentation like that of the female. Dorsal outline of carapace panduriform, pointed posteriorly. Central ventral portion of valve strongly inflated posterior to S2; anteroventral area less inflated. In ventral view, two spurs, one on each valve, converge anteriorly at the anteroventral corner. A small velate ridge parallels the free edge of the contact margin in the central ventral region. Area between the velate ridge and contact margin pitted.

Anterior cardinal angle approximately 115°; posterior cardinal angle approximately 120°.

Measurements.—Greatest length through the geniculum; greatest height located at about one-third the distance from the an-

terior end; greatest width in anterior half. Dimensions of typical adult specimens are (mm.):

	length	height	width
male	0.60	0.32	0.30
female	0.67	0.40	0.36

Remarks.—*Tetrasacculus paeneteichus*, n. sp., differs from the female of *T. bilobus* Stewart, from the Silica shale of Ohio, in having four complete and one incomplete loculi, a more tapered posterior end and a more inclined sulcus. The presence of the spurs on the male of the new species is diagnostic. *T. paeneloculatus* Kesling & Weiss from the Norway Point formation of Michigan has only four loculi on the female and the male lacks spurs.

Occurrence.—Common at loc. 7 and 8; rare at loc. 9.

Specimens.—Holotype, a female carapace, NYSM 10848, loc. 7; allotype, a male carapace, NYSM 10849 loc. 8; paratypes, a male carapace, NYSM 10850, and a female carapace, NYSM 10847, loc. 7.

TETRASACCULUS cf. T. MAGNIVELATUS
Kesling & McMillan
Pl. 112, fig. 19,20

[cf.] *Tetrasacculus magnivelatus* KESLING & MCMILLAN, 1951, p. 51, pl. 1, fig. 6,7.
[cf.] *Tetrasacculus magnivelatus* KESLING, 1953b, pl. 4, fig. 1–21.

Remarks.—In the specimens from the Windom shale the velate ridge fails to curve around the posteroventral projection or to meet the anterior spur. The posteroventral projection is also more elongate than in the forms from the Arkona shale of Ontario. Other features agree with those described by Kesling (1953b).

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Hypotype, a male left valve, NYSM 10846, loc. 7. Unfigured specimens, two incomplete male left valves, loc. 7.

Genus SUBLIGACULUM Kesling & McMillan

Type species: By original designation, *Subligaculum scrobiculum* Kesling & McMillan, 1951, p. 65–66.

SUBLIGACULUM ACULEATUM, n. sp.
Pl. 111, fig. 18–20

Description of female.—Carapace small; exclusive of frill the lateral outline is semicircular. Panduriform in dorsal view; dorsal border straight. Hinge line straight, approximately seven-eighths as long as the valve.

Bilobate; anterior lobe small, hemispherical, and extends from a little below the dorsal border to midheight. Posterior lobe larger than anterior lobe and more dorsad; greatest inflation adjacent to S2. Short, horizontally elongate ventral lobe located ventrad to major sulcus and confluent with anterior and posterior lobes.

Unisulcate; S2 slightly anterior to midlength, deep and extending from the dorsal border to the center of the valve. Sulcus laterally constricted at its midlength. Lateral surface generally projects above the hinge line in the anterodorsal area.

Frill moderately high extends from the central anterior area around the free border to a little posterior of S2. The frill is fluted, with each flute marking the position of one of the four halves of the chamberettes. Chamberettes progressively smaller posteriorly. Two large, smooth, curved spurs, one on each valve, project outward and downward from the posteroventral corner. A small blunt spine extends posterodorsally from the posteroventral corner. Lateral surface coarsely granulose with scattered papillae near the frill. Free edge of contact margin ornamented with a row of very small papillae.

Anterior cardinal angles approximately 115°.

Measurements.—Greatest length a little above midheight; greatest height through the anterior lobe; greatest width through the ventral lobe. Dimensions of the holotype are: length, 0.72 mm.; height, 0.48 mm.; width, 0.28 mm.; maximum height of frill, 0.10 mm.

Remarks.—No males of *Subligaculum aculeatum*, n. sp., were found. This species differs from the female of *S. laciniosum* Kesling, 1952c, from the Ferron Point formation of Michigan, which it closely resembles, in having a wider frill, more pronounced lobes, a deeper sulcus, and a small spine at the posterior corner.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Holotype, a female carapace, NYSM 10830, loc. 7; paratypes, a female left valve, NYSN 10831, loc. 8, and another female left valve, NYSM 10832, loc. 7.

SUBLIGACULUM LACINIOSUM Kesling
Pl. 111, fig. 15–17

Subligaculum laciniosum KESLING, 1952c, p. 54–55, pl. 2, fig. 16–18.

Remarks.—The lobation on the Windom specimens is more prominent than on those from the Ferron Point formation of Michigan. Also, the frill is less fluted and the spur is closer to the frill. All these minor differences are regarded as individual variations.

Occurrence.—Rare at loc. 8.

Specimen.—Hypotype, a female carapace, NYSM 10829.

Family DREPANELLIDAE Swartz, 1936
Genus RICHINA Coryell & Malkin

Type species: By original designation *Richina truncata* Coryell & Malkin, 1936, p. 3, fig. 5,5a, and 6.

RICHINA SELENICRISTATA, n. sp.
Pl. 113, fig. 7–9

Description.—Carapace sublanceolate in dorsal view, subovate in lateral view. Dorsal border straight; anterior and posterior borders unequally rounded, greatest extension in dorsal half; ventral border convex. Hinge line sansabelloid; approximately two-thirds as long as the valve. Right valve noticeably larger than left, overlap conspicuous along the entire free border.

In lateral view a well defined, arcuate, rounded ridge lies just inside the parallel to the anterior border, extending from the anterior corner to below S2 where it narrows and merges with the surface.

L2 a vertically elongate node, widest ventrally and extending from the dorsal border to about one-third the distance to the ventral border; L3 smaller than L2, conical, with the apex directed posterodorsally. Yoke connecting the anterior margins of L2 and L3 narrow, only gently inflated.

S2 narrow, J-shaped, extending from a little below the dorsal border to the base of L2. S1 arcuate, parallels the inner edge of the anterior ridge. The deeper dorsal portion of S1 separates the ridge from L2, whereas the ventral half separates the ridge from the yoke.

Entire surface granulose.

Anterior cardinal angle approximately 160°; posterior cardinal angle approximately 140°.

Measurements.—Greatest length at approximately one-third the distance from the dorsal to the ventral border; greatest height a little posterior to S2; greatest convexity central. Dimensions of a typical carapace are: length, 1.16 mm.; height, 0.75 mm.; width at center, 0.46 mm. and between the tips of L3, 0.54 mm.

Remarks.—The distinguishing features of *Richina selenicristata*, n. sp., are the anterior marginal ridge and the sansabelloid hinge line. In addition to those features, the new species differs from *R. truncata* Coryell & Malkin, from the Widder beds of Ontario, Canada, in having a J-shaped S2, and a poorly defined yoke.

Occurrence.—Common at loc. 8; rare at loc. 1, 2, 7 and 9.

Specimens.—Holotype, a carpapace, NYSM 10851; three paratypes, a carapace, NYSM 10852, a right valve, NYSM 10854, and a left valve, NYSM 10853. All types from loc. 8.

RICHINA sp.
Pl. 113, fig. 10

Remarks.—A single left valve differs from the typical specimens of *Richina selenicristata*, n. sp., by having a more elongate lateral outline, an acuminate posterior end and a smooth surface. Some of the elongation is probably the result of crushing, for the specimen is badly fractured in its posterior half. However, the difference in height is too great to be explained by crushing alone.

Occurrence.—Loc. 8.

Specimen.—A left valve, NYSM 10855.

Genus *Bollia* Jones & Holl

Type species: *Bollia uniflexa* Jones & Holl, 1886, by subsequent designation of Miller, 1892, p. 706.

BOLLIA HINDEI Jones, 1890
Pl. 113, fig. 11

Bollia hindei JONES, 1890, p. 540, pl. 20, fig. 5.
Bollia widderensis CORYELL & MALKIN, 1936, p. 2, fig. 4,4a.
Bollia hindei [partim] WARTHIN, 1937, Card 41.
Bollia hindei SWARTZ & SWAIN, 1941, p. 419, pl. 3, fig. 5a-f.
Bollia hindei STEWART, 1950, p. 657, pl. 85, fig. 8–9.

Remarks.—The few excellently preserved specimens clearly show all the features

described by Swartz & Swain (1941) for their forms from the Hamilton at Thedford, Ontario. Particularly well illustrated are the narrow U-shaped furrow which parallels the free border, and the granulose surface texture.

Occurrence.—Rare at loc. 1, 2, 7, and 8.

Specimens.—Hypotype, a right valve, NYSM 10856, loc. 7.

Genus ULRICHIA Jones

Type species: By original designation, *Ulrichia conradi* Jones, 1890, p. 543, fig. 2.

ULRICHIA VENTURA, n. sp.
Pl. 113, fig. 23–25.

Description.—Carapace subelliptical in lateral view, subquadrate in ventral view. Dorsal border straight; anterior and posterior borders evenly rounded; ventral border straight, parallel to the dorsal border. Hinge line straight, invaginated as viewed dorsally.

L2 a small, conical node, vertically erect, and extending above the hinge line for about one-third its own height. L3 also a small node, ellipsoidal, narrower than L2. Base of L3 slightly more dorsal than the base of L2, and extends farther above the hinge line. L2 and L3 close together, separated by short, shallow S2 extending from the hinge line to the base of L2 and situated slightly anterior to midlength.

Distinct outwardly flared, smooth, velate ridge extends around the free border. Velate ridge reduced to approximately half its greatest width along the ventral border. Free edge of the contact margin ornamented with a row of widely spaced papillae on each valve. Papillae alternate on each valve. Dorsal margin with a narrow smooth ridge confluent with the velate ridge at the anterior corner, but projecting beyond the velate ridge at posterior corner, thereby forming a small recess.

Lateral surface with gentle swelling ventral to L2 and S2. Surface reticulate; nodes scantily pitted.

Anterior cardinal angle approximately 120°; posterior cardinal angle approximately 115°.

Measurements.—Greatest length midway between the dorsal and ventral borders; greatest height central, but essentially uniform between the dorsal and ventral borders; greatest width through the anterocentral swelling. Dimensions of the holotype are: length, 0.72 mm.; height, 0.38 mm.; width, 0.25 mm. and width of the velate ridges at the posterior end, 0.19 mm.

Remarks.—*Ulrichia ventura*, n. sp., differs from *U. conradi* Jones, which it closely resembles, in having a vertical anterior node and a reduced velate ridge along the ventral margin. The nodes of the new species are also closer together.

Occurrence.—Rare at loc. 5 and 7.

Specimens.—Holotype, a carapace, NYSM 10864, loc. 7; paratype, another carapace, NYSM 10865, loc. 5.

ULRICHIA SPINIFERA Coryell & Malkin
Pl. 113, fig. 14–17

Ulrichia conradi WARTHIN, 1934, p. 213, pl. 1, fig. 10.
Ulrichia spinifera CORYELL & MALKIN, 1936, p. 1–2, fig. 1,2.
Ulrichia conradi STEWART, 1936, p. 747, pl. 100, fig. 17,18.
Ulrichia spinifera [partim], WARTHIN, 1937, card 94, fig. 1,1a,2.
Ulrichia spinifera KESLING, 1952d, p. 27, pl. 4, fig. 9–12.
Ulrichia spinifera KESLING & WEISS, 1953, p. 19, pl. 3, fig. 32–35.

Remarks.—The specimens identified as *Ulrichia spinifera* Coryell & Malkin from the Windom member have a stronger posterior swing than the specimens illustrated by Kesling (1952d) from the Bell shale and Kesling & Weiss (1953) from the Norway Point formation. Also, in the Windom specimens L2 is much broader at its base than L3 and both nodes are sparcely pitted. As seen in ventral view, the outer margins of the velate ridges converge slightly posteriorly. Parallel to the free edge of the contact margin on each valve is a narrow ridge; the inner edge of the ridge is studded with widely spaced papillae, so arranged that in a complete, closed carapace the papillae are alternately aligned.

Occurrence.—Common at loc. 8; rare at loc. 1 and 5.

Specimens.—Hypotypes, two carapaces, NYSM 10859, 10860, from loc. 8.

ULRICHIA ACRICULA Kesling
Pl. 113, fig. 18–22

Ulrichia acricula KESLING, 1952d, p. 28, pl. 4, fig. 1–8.

Remarks.—On the specimens from the Windom shale L2 is a conical rather than knoblike, and is scantily pitted, especially near it base.

Occurrence.—Common at loc. 7; rare at loc. 6 and 9.

Specimens.—Hypotypes, a carapace, NYSM 10861, and two right valves, NYSM 10862, 10863, from loc. 7.

ULRICHIA FRAGILIS Warthin
Pl. 113, fig. 12

Ulrichia fragilis WARTHIN, 1934, p. 213–214, pl. 1, fig. 11; STEWART, 1936, p. 747, pl. 100, fig. 19,20; WARTHIN, 1937, Card 95; KESLING, 1952d, p. 22, pl. 4, fig. 22–24; KESLING & WEISS, 1953, p. 49, pl. 3, fig. 23–26

Remarks.—The reticulated surface pattern extends far up along the anterior edge of L3, and the reticulations posterior to L3 are finer than those on the rest of the surface circumscribed by the semicircular velate ridge. The major sulcus is narrow, vertically elongate and closer to L2 than L3. A narrow J-shaped ridge outlines the ventral and posteroventral edges of the sulcus. Except for the minor refinements described above, which are probably seen because of better preservation, the forms from New York are nearly identical with those from Michigan described by Warthin (1934).

Occurrence.—Rare at loc. 5 and 7.

Specimen.—Hypotype, a right valve, NYSM 10857, loc. 7.

ULRICHIA ILLINEARIS Kesling
Pl. 113, fig. 13

Ulrichia illinearis KESLING, 1953a, p. 199–200, pl. 1, fig. 28–32.

Remarks.—Most of the specimens from the Windom shale have the nodes abraded and carapace flattened. In spite of this, the small marginal denticles are present on some specimens.

Occurrence.—Common at loc. 7; rare at loc. 5 and 8.

Specimen.—Hypotype, a carapace, NYSM 10858, loc. 7.

Family KLOEDENELLIDAE Ulrich & Bassler, 1908
Genus EUKLOEDENELLA Ulrich & Bassler

Type speces: By original designation, *Eukloedenella umbilica* Ulrich & Bassler, 1923, p. 669, pl. 57, fig. 8–12.

EUKLOEDENELLA sp.
Pl. 114, fig. 21,22

Description.—Carapace subquadrate in lateral view, elliptical in dorsal view. Right valve slightly larger than left, overlap inconspicuous except at anterodorsal border. Dorsal border gently convex, anterior border semicircular, ventral border gently curved in anterior half, straight in posterior half; posterior border broadly rounded, radius of curvature greatest in dorsal half. Hinge life straight and invaginated in posterior half; hidden in anterior half due to overlap by triangular extension of right valve. Posterior corner with small overlapping process on right valve.

Laterial surface convex, without angulations and widest posteriorly. Small, narrow, arcuate sulcus, convex posteriorly extends from just below the dorsal border to approximately one-third distance to the ventral border. Anterior border of both valves with slender marginal ridge. All surfaces smooth.

Anterior cardinal angle approximately 150°; posterior cardinal angle approximately 100°.

Measurements.—Greatest length through base of sulcus; greatest height slightly anterior to sulcus; greatest width through posterior third of carapace. Dimensions of the illustrated carapace are: length, 1.00 mm.; height, 0.57 mm.; width, 0.42 mm.

Remarks.—This species differs from *Eukloedenella doverensis* Turner, 1939, from the Middle Devonian of Ontario by having an arcuate sulcus, a narrower anterior marginal ridge, and a less pronounced posterior widening. The specimen illustrated on Pl. 114, fig. 21,22, is believed to be a female. The hypothetical outline of the male, based on comparisons with descriptions and illustrations of both sexes of other Devonian and some Silurian species, is superimposed on the illustration of the female (Pl. 114, fig. 22).

Occurrence.—Rare at loc. 8.

Specimen.—One female carapace, NYSM 10885.

Genus NEOKLOEDENELLA Croneis & Funkhauser

Type species: By original designation, *Neokloedenella prima* Croneis & Funkhauser, 1938, p. 341–342, pl. 10, fig. 8–10.

NEOKLOEDENELLA sp.
Pl. 114, fig. 23–25

Description of female.—Carapace of medium size, subrectangular in lateral view, ovate in dorsal view, subcircular in posterior view; elliptical in anterior view. Right valve slightly larger than left; overlap inconspicuous. Dorsal border straight or slightly arched centrally, anterior border semicircular; ventral border gently curved, posterior border broadly rounded, greatest extension in the dorsal half. Hinge line straight in posterior half, slightly depressed; hidden in anterior half by overlapping triangular process on right valve. Posterodorsal process on right valve poorly developed.

Lateral surface with small, faint, shallow depression in the central dorsal area anterior of center. Anterior and ventral areas of each valve with an extremely narrow marginal ridge. Posterior one-third of carapace strongly swollen, rest of lateral surface moderately convex. All surfaces smooth.

Anterior cardinal angle approximately 150°; posterior cardinal angle approximately 120°.

Description of male.—General outline and overlap like that of female. The male lacks the posterior swelling, and the marginal ridge paralleling the free border is less well developed.

Measurements.—Greatest length midway between the dorsal and ventral borders; greatest height through the posterior quarter; greatest width in female through the posterior quarter, in the male through the center. Dimensions of the male left valve and a female carapace are (mm.):

	length	height	width
male	1.20	0.62	0.28
female	1.24	0.67	0.60

Remarks.—The specimens from the Windom differ from the type species, *Neokloedenella prima*, from the Clore formation (Upper Mississippian) of Illinois, by having a narrow marginal ridge, a less well developed posterior process on the right valve and a greater size. This is the first reported occurrence of *Neokloedenella* in rocks older than Mississippian.

Occurrence.—Rare at loc. 8.

Specimens.—A female carapace, NYSM 10886, and a male left valve, NYSM 10887, both from loc. 8.

Genus JONESINA Ulrich & Bassler

Type species: *Beyrichia fastigiata* Jones & Kirkby, 1867, by original designation of Ulrich & Bassler, 1908, p. 324.

JONESINA APOGLYPHA, n. sp.
Pl. 114, fig. 26–29

Description of male.—Carapace small; subrhomboidal in lateral view, subrectangular in dorsal view. Dorsal border straight or gently concave centrally; ventral border gently curved; anterior border evenly rounded on left valve, unevenly rounded on right valve with greater radius of curvature in dorsal half; posterior border very broadly rounded, greatest extension of dorsal half. Hinge line straight, approximately two-thirds as long as the valve; posterior one-third depressed. Right valve slightly larger than left and with triangular shaped overlapping process at anterior corner, and a smaller process at the posterior corner.

S2 anterior to center; extends from dorsal margin to a little above the center. Sulcus either slightly arcuate or vertical, generally wider at its ventral termination. A small subelliptical L2 is situated well below the dorsal border and adjacent to S2. Lateral surface with two unornamented ridges on each valve. Anterior ridge extends vertically from the anterior corner to midheight; anterior slope of ridge merges with lateral surface, posterior slope steeper and more clearly defined. Posterior ridge located just inside the posterior border and extends subvertically from a little below the posterior corner almost to the posteroventral border; posterior slope steep, anterior slope less steep, but distinct.

Ventral half of valves gently inflated; a relatively wide marginal band parallels the entire border. L2, S2, ridges, marginal band, central ventral, ventrocentral and anteroventral areas smooth; remainder of surface with polygonal reticulations. On some specimens, the anterior marginal area is smooth.

Description of female.—General outline, lobation and sulcation like those in the male. The female is wider than the male in the posterior half of the carapace and has reticulations on the ridges and the anterior marginal area.

Measurements.—Greatest length through base of S2; height nearly uniform between dorsal and ventral borders; greatest width through posterior half. Dimensions of the holotype and allotype are (mm.):

	length	height	width
holotype	0.71	0.38	0.31
allotype	0.70	0.36	0.14

Remarks.—This distinctive little species is easily recognized by the two ridges on each valve and the large unreticulated area in the ventral portion of the valves.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Holotype, a female carapace, NYSM 10888, loc. 8; paratypes, a left valve, NYSM 10889, loc. 7, and a right valve, NYSM 10890, loc. 8.

Family BEYRICHIIDAE Jones, 1894
Genus HIBBARDIA Kesling

Type species.—*Amphissites lacrimosa* Swartz & Oriel, 1948, by original designation of Kesling, 1953d, p. 19.

HIBBARDIA LACRIMOSA (Swartz & Oriel)
Pl. 115, fig. 1,2

Amphissites lacrimosa SWARTZ & ORIEL, 1948, p. 553–554, pl. 79, fig. 15.
Hibbardia lacrimosa KESLING, 1953d, p. 19–24, pl. 8,9.

Remarks.—Kesling (1953d) suggested that the worn valve described and illustrated by Swartz & Oriel (1948) from the Windom shale, may have come from redeposited Wanakah shale since no specimens were found in the overlying Windom or Kashong shales. However, the large number of beautifully preserved specimens from the Windom member, especially the instars which make up the bulk of the collection, indicates that the range of *Hibbardia lacrimosa* can be safely extended to include the Moscow formation.

Occurrence.—Abundant at loc. 7; common at loc. 8 and 9; rare at loc. 1, 2, 4 and 5.

Specimens.—Two carapaces, 6th instar, hypotypes, NYSM 10891, 10892, loc. 7.

Genus PHLYCTISCAPHA Kesling

Types species: By orginal designation, *Phlyctiscapha rockportensis*, Kesling, 1953c, p. 222–225, pl. 1,2.

PHLYCTISCAPHA SUBOVATA Smith
Pl. 115, fig. 3

Phlyctiscapha subovata SMITH, 1956, p. 2–3, pl. 1, fig. 1–3.

Remarks.—Although eighteen specimens of this species were found, none is an adult, and all except three of the instars were crushed, distorted or abraded.

Occurrence.—Common at loc. 8, rare at loc. 9.

Specimen.—Hypotype, an immature carapace, loc. 8, NYSM 10893.

Family PRIMITIIDAE Ulrich & Bassler, 1923 emended by Swartz, 1936
Genus PUNCTOPRIMITIA Stewart & Hendrix

Type species: *Haploprimitia simplex* Stewart, 1936, by original designation of Stewart & Hendrix, 1945a, p. 90.

PUNCTOPRIMITIA SUBAEQUALIS Swartz & Oriel
Pl. 115, fig. 23–27

Punctoprimitia subaequalis SWARTZ & ORIEL, 1948, p. 550–551, pl. 79, fig. 4,5; KESLING, 1952d, p. 25, pl. 2, fig. 2–4; KESLING & WEISS, 1953, p. 34–35, pl. 3, fig. 2–7.

Remarks.—The complete carapace, previously undescribed, is small, pandiriform in dorsal view, from nearly semicircular to subelliptical in lateral view and subcircular in anterior view. The left valve is slightly larger than the right.

There is considerable variation in the posterior cardinal angle, measuring from 95° to 122°. Immediately ventrad to the median sulcus is a circular unornamented area on most specimens. The general outline of the valves in lateral view changes from nearly semicircular in small specimens to subelliptical in larger forms. This elongation is probably due to increased growth in the posterior extralobate area of the valve concomitant with only nominal growth over the rest of the valve.

Occurrence.—Abundant at loc. 7; common at loc. 4 and 5; rare at loc. 3, 6, 8 and 9.

Specimens.—Hypotypes, two carapaces, NYSM 10918, 10919, two left valves, NYSM 10915, 10916, and a right valve, NYSM 10917, from loc. 7.

Family ACRONOTELLIDAE Swartz, 1936
Genus MONOCERATINA Roth

Type species: By original designation, *Monoceratina ventralis* Roth, 1928, p. 15–19, text-fig. 8–11.

MONOCERATINA CASEI Warthin
Pl. 116, fig. 15

Monoceratina casei WARTHIN 1934, p. 207, pl. 1, fig. 1; ——, 1937, Card 16; KESLING & WEISS, 1953, p. 48, pl. 3, fig. 8–11.

Occurrence.—Rare; only one carapace found at loc. 7.

Specimen.—Hypotype, a carapace, NYSM 10933.

Superfamily CYPRIDACEA
Family CYTHERELLIDAE Sars, 1865
Genus BIRDSALLELLA Coryell & Booth

Types species: By original designation, *Birdsallella simplex*, Coryell & Booth, 1933, pl 273, fig. 6,7.

BIRDSALLELLA CATENA, n. sp.
Pl. 114, fig. 1–3

Description.—Carapace subelleptical in lateral view; subtriangular in dorsal view. Dorsal border slightly arcuate; anterior border semicircular; posterior border narrowly rounded, attenuate centrally; ventral border concave in the central portion. Right valve larger than left; overlap strong, least noticeable along the posterior margin. Hinge line slightly arcuate near the anterodorsal corner.

Slightly anterior to the posterior border, the lateral surface is elevated to form a distinct, lip-like, arcuate ridge, convex posteriorly. Posterior slope of ridge short, abrupt; in dorsal view the slope is convex posteriorly. Anterior slope of ridge long and gentle, but the surface rises again just inside the anterior border to form a second, but less conspicuous ridge. Surface from anterior ridge to anterior border moderately inclined.

Lateral surface between the ridges faintly reticulated; reticulations chain-like and tend to be longitudinally aligned. An indistrict adductor muscle scar lies dorsal and slightly anterior of center. Exclusive of the area between the ridges, the surface is smooth.

Measurements.—Greatest length central; greatest height slightly anterior to the posterior ridge, but is nearly uniform throughout; greatest width between the posterior ridges. Dimensions of the holotype are: length, 0.92 mm.; width, 0.40 mm.; height, 0.48 mm.

Remarks.—The orientation followed here is based on the position of the adductor muscle scar which is nearer the narrower end, and, therefore, places the greatest width posterior, as is the case in living ostracodes (Kesling, 1951). This is contrary to the orientation initiated by Coryell & Booth (1953) and followed by Stewart (1936, 1950), but agrees with that used by Kesling & Weiss (1953).

Birdsallella catena differs from *B. tumida* Stewart, 1936 from the Silica shale of Ohio by having a subordinate anterior ridge on each valve, a more elongate lateral outline and a faintly reticulated surface between the ridges. However, the reticulations are not always discernible.

Occurrence.—Common at loc. 7, rare at loc. 8, 9.

Specimens.—Holotype, carapace, NYSM 10869; paratypes, two carapaces, NYSM 10870, 10871. All types from loc. 7.

BIRDSALLELLA DEVONICA Coryell & Malkin
Pl. 114, fig. 4–6

Birdsallella devonica CORYELL & MALKIN, 1936, p. 17, fig. 33.

Remarks.—On the average this species is larger than *B. catena*, n. sp., and has the posterior end higher than the anterior end. The surface of *B. devonica* is very finely granulose. Nearly all of the specimens are pigmented in one or more shades of red, brown or gray. The dorsal border of the Windon specimens is less arcuate than in those from the Widder beds described by Coryell & Malkin.

Occurrence.—Common at loc. 7; rare at loc. 1, 2, 8 and 9.

Specimen.—Hypotype, a carapace, NYSM 10872, loc. 7.

Genus PUNCTOMOSEA, n. gen.

Type species: *Thrallella cristata* Swartz & Oriel, 1948, p. 561–562, pl. 79, fig. 22,23.

Description.—Carapace of moderate size, ovate to subreniform in lateral view, subtrapazoidal in dorsal view. Dorsal border

arcuate; ventral border straight or concave in central part; posterior border broadly rounded; anterior border long, narrowly rounded, acuminate subcentrally. Left valve larger than right; overlap conspicuous along all borders. Lateral surface of both valves abruptly elevated just inside the posterior border to form distinct ridge; surface strongly reticulated anterior to the posterior ridge. Rest of surface smooth, pitted or both.

Remarks.—*Punctomosea* differs from *Bythocyproidea* Stewart & Hendrix (1945a) by having a prominent posterior ridge on each valve and a deeply reticulated surface anteriorly adjacent to the ridge.

Coley (1954) declared *Thrallella* a junior synonym of *Menoeidina* and emended the description of *Menoeidina* to include all species previously assigned to *Thrallella*. However, *Thrallella cristata* Swartz & Oriel, exclusive of its general ornamentation, has little in common with *Menoeidina*. Besides being considerably larger than *Menoeidina*, it has a much shorter hinge line proportional to the length of the carapace and has a decided inequality in height at the extremities. For these reasons, the writer feels justified in referring *Thrallella cristata* to a new genus.

PUNCTOMOSEA CRISTATA (Swartz & Oriel)
Pl. 113, fig. 26–29

Thrallella cristata SWARTZ & ORIEL, 1948, p. 561–562, pl. 79, fig. 22,23.
Menoeidina cristata COLEY, 1954, p. 461–462.

Supplementary description.—Carapace of moderate size; left valve larger than right and conspicuously overlapping the latter around the dorsal and entire free border. Dorsal border short, arcuate; anterior end narrowly rounded with long moderately sloping anterodorsal border; posterior border broadly rounded on right valve, broadly rounded and acuminate centrally on left valve; ventral border straight on left valve, concave in the central part on the right valve. Hinge line straight, approximatey half the maximum length of the valve.

An arcuate lip-like ridge, convex posteriorly, lies slightly anterior to the posterior border. Posterior slope of ridge concave and recessed beneath the lip of the ridge in the outer half, convex in the inner half. Forward slope of lateral surface long and gentle; uniform on the left valve, right valve with moderately steep anterior termination. Anterior and immediately adjacent to the posterior ridge, the lateral surface is ornamented with an ovate mass of coarse reticulations or deep pits. Anterocentral area usually with fewer and smaller pits, but may lack pits entirely. Rest of surface smooth or minutely granulose. A narrow, rounded, marginal ridge parallels the anterior and posterior borders of both valves, but is less distinct on the right valve. Hinge line confined to the posterior half of the carapace and is depressed. Hinge line depression is a wide V-shaped furrow, bounded laterally by the dorsal edges of the posterior ridges and is best seen in dorsal view.

Internally a subelliptical adductor muscle scar is located slightly posterior of center and is bounded posteriorly by an internal, well defined rige and anteriorly by second poorly developed ridge. The external pits and reticulations are expressed internally by faint, rounded spots.

Measurements.—Greatest length at approximately three-fourths distance from the dorsal to the ventral border; greatest height located about one-third the length from the posterior end; greatest width through the posterior reticulations. Dimensions of a typical adult carapace are: length, 1.00 mm.; height, 0.64 mm.; width, 0.48 mm.

Occurrence.—Common at loc. 5. 7 and 9; rare at loc. 2 and 8.

Specimens.—Hypotypes, a right valve, NYSM 10868, and a carapace, NYSM 10866, from loc. 7. Another carapace, NYSM 10867, from loc. 9.

Genus SULCELLA Coryell & Sample

Type species: By orginal designation, *Sulcella sulcata* Coryell & Sample, 1932, p. 274, pl. 26, fig. 18.

SULCELLA EMICATUSA, n. sp.
Pl. 114, fig. 7,8

Description.—Carapace medium sized; elliptical in lateral view, sublanceolate in dorsal view. Dorsal border gently curved; anterior and posterior borders symmetrically rounded; ventral margin straight centrally, curved terminally. Overlap prominent, most conspicuous along the ventral and anterodorsal borders. Hinge line arcuate; hingement not observed.

Lateral surface with low, arcuate, lip-like ridge, subparallel to the posterior border; posterior marginal surface very steep on the left valve, less steep on the right valve. In dorsal view, the lateral surface anterior to the ridge narrows toward the anterior border. A small pit on each valve is located slightly anterodorsal of center. On the right valve only, this pit lies in a small depression. Anterior border of the left valve margined by a low ridge; anterior marginal ridge only faintly developed on the right valve. Surface smooth. As seen in dorsal view, the hinge line has a slight sinuosity most strongly developed in the anterior half.

Measurements.—Greatest length midway between the dorsal and ventral borders; height essentially uniform between the dorsal and ventral borders; greatest width between the posterior ridges. Dimensions of the holotype are: length, 0.96 mm.; height, 0.56 mm.; width, 0.44 mm.

Remarks.—Comparison of this species with the illustrations and description of the types species (Cooper, 1946) indicates that the specimens described above are females. No males of the new species were found.

Sulcella emicatusa, n. sp., differs from *S. sulcata* Coryell & Sample from the Pennsylvanian of Texas by having more prominent posterior ridges and having the crests of the ridges surmounted by small, lip-like extensions. Other reported occurrences of this genus are from Upper Paleozoic formations only.

Occurrence.—Rare at locality 8.

Specimens.—Holotype, a carapace, NYSM 10873; paratype, another carapace, NYSM 10874, both from loc. 8.

Genus BYTHOCYPROIDEA Stewart & Hendrix

Type species: By orginal designation, *Bythocyproidea sanduskyensis* Stewart & Hendrix, 1945a, p. 91–92, pl. 10, fig. 26–28.

BYTHOCYPROIDEA cf. B. ERIENSIS Stewart & Hendrix
Pl. 114, fig. 9,10

[cf.] *Bythocyproidea eriensis* STEWART & HENDRIX 1945a, p. 92, pl. 10, fig. 23–25.

Remarks.—A single carapace resembling *Bythocyproidea eriensis* was found. The specimen differs from the latter by having its greatest height midway between the anterior and posterior borders, a less steep posterodorsal border and a weak posterior ridge on the left valve. On the other hand, the specimen shares with *B. eriensis* the following features: (1) strong overlap of the left valve over the right, with exceptionally thick borders on the left valve, (2) a prominent posterior elevation surmounted by a low, lip-like, arcuate ridge on the right valve, (3) a few scattered pits anterior to the posterior ridge and (4) the same general outline and convexity.

In size, the Windom specimen compares favorably with the largest syntype of *B. eriensis*. Dimensions of the illustrated specimen are: greatest length, 1.04 mm., measured midway between the dorsal and ventral borders; greatest height, 0.58 mm.; and greatest width, 0.40 mm., measured between the posterior shoulders.

Occurrence.—Rare at locality 7.

Specimen—A carapace, hypotype, NYSM 10875.

Genus MENOEIDINA Stewart

Type species: By original designation, *Menoeidina subreniformis*, Stewart, 1936, p. 762, pl. 102, fig. 22–24.

MENOEIDINA VERSICULA, n. sp.
Pl. 114, fig. 15–19

Description.—Carapace small, subovate to subreniform in lateral view, sublanceolate in dorsal view. Dorsal border arched centrally; posterior border subvertical, corners rounded; ventral border straight or slightly concave in the central portion; anterior border evenly rounded. Left valve larger than right; overlap noticeable except along posterodorsal and posterior borders. Hingement not observed.

Lateral surface abruptly elevated close to the posterior border to form arcuate ridge, convex posteriorly. Posterior slope of ridge short and steep. Lateral surface anterior to the ridge of nearly uniform width to the central area, then gradually diminishes in width toward the anterior border. Lateral surface slightly depressed a little anterior of center in some specimens. Inner posterior edge of ridge scarred with four to six small, horizontally elongate grooves; anterocentral area with three or four grooves. Rest of surface smooth.

Measurements.—Greatest length midway

between dorsal and ventral borders; greatest height central; greatest width in posterior half. Dimensions of a typical carapace are: length, 0.56 mm.; height, 0.34 mm.; width, 0.24 mm.

Remarks.—This species differs from *Menoeidina scopeli* Coley from the Ludlowville of New York by lacking a definite anterior ridge and numerous circular pits parallel to the ridges. Specimens of *M. versicula* vary considerably in shape, ranging from short and obese to elongate and slender.

Occurrence.—Common at loc. 7, rare at loc. 2, 5 and 9.

Specimens.—Holotype, a carapace, NYSM 10880; paratypes, three carapaces, NYSM 10881, 10882, 10883; all types from loc. 7.

MENOEIDINA MULTIPUNCTATA, n. sp.
Pl. 114, fig. 11–14

Description.—Carapace small, subreniform in lateral view, subrectangular in dorsal view. Dorsal border gently arched just anterior of center; anterior border evenly rounded, ventral border concave in central portion, posterior border very broadly rounded, radius of curvature less in dorsal half. Left valve larger than right; overlap most conspicuous along anterior and ventral borders, absent along posterodorsal border. Hinge line straight, covered by overlap in central dorsal portion. Hingement not observed.

Lateral surface abruptly elevated to form a narrow ridge subparallel to and just inside the posterior border. Lateral surface anterior to the ridge narrows gradually almost to anterior border, then slopes moderately to the anterior border.

Central area very gently swollen. Elevated posterior half of lateral surface ornamented with from sixteen to twenty-five small, nearly circular pits, the most posterior ones paralleling the ridge, the others suggesting a subhorizontal alignment; anterocentral area with from none to twelve irregularly arranged pits. Rest of surface smooth.

Anterior border with narrow marginal ridge, slightly smaller on the right valve.

Measurements.—Greatest length midway between dorsal border and center; greatest height slightly anterior of midlength, greatest width central. Dimensions of the holotype are: length, 0.56 mm.; height, 0.[illegible] mm.; width, 0.23 mm.

Remarks.—*Menoeidina multipunctata*, n. sp., may be distinguished from *M. phraseolina* Stewart & Hendrix from the Olentangy shale of Ohio by the narrow anterior ridge, the central dorsal overlap, the anterocentral pits, and by having the greatest height anterior of center. The new species may be separated from *M. arcuata* Turner from the Hamilton of Ontario by its shape which is

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EXPLANATION OF PLATE 113

(All magnifications ×30 unless otherwise indicated)

FIG. *1–6*—*Tetrasacculus paeneteichus*, n. sp. *1,2*, Right lateral and dorsal views of female carapace, paratype, NYSM 10847. *3*, Ventral view of female carapace showing loculi and pitted channel, holotype, NYSM 10848. *4,6*, Right lateral and ventral views of male carapace, allotype, NYSM 10849. *5*, Dorsal view of male carapace, paratype, NYSM 10850. (p. 1108)

7–9—*Richina selenicristata*, n. sp. *7*, Left lateral view of carapace, paratype, NYSM 10852. *8,9*, Right lateral and dorsal views of carapace, holotype, NYSM 10851, ×25. (p. 1108)

10—*Richina* sp., Lateral view of left valve, NYSM 10855. ×25. (p. 1108)

11—*Bollia hindei* Jones. Lateral view of right valve, hypotype, NYSM 10856. ×15. (p. 1108)

12—*Ulrichia fragilis* Warthin. Lateral view of right valve, hypotype, NYSM 10857. (p. 1110)

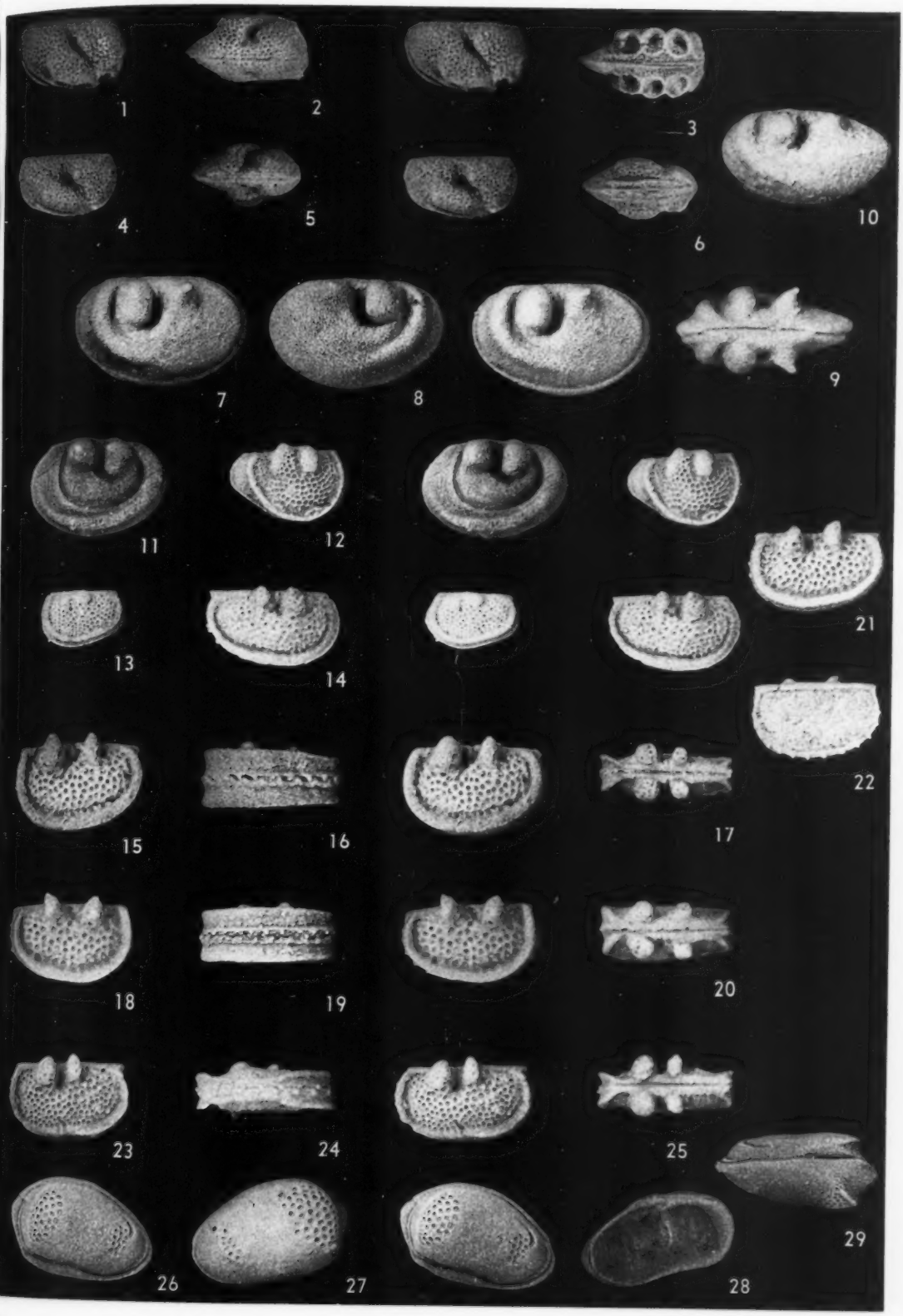
13—*Ulrichia illinearis* Kesling. Left lateral view of carapace, hypotype, NYSM 10858. (p. 1110)

14–17—*Ulrichia spinifera* Coryell & Malkin. *14,17*, Right lateral and dorsal views of carapace, hypotype, NYSM 10859. *15,16*, Left lateral and ventral views of a larger carapace, hypotype, NYSM 10860. (p. 1109)

18–22—*Ulrichia acricula* Kesling. *19–21*, Ventral, dorsal and left lateral views of carapace, hypotype, NYSM 10861. *18*, Lateral view of right valve, hypotype, NYSM 10862. *22*, Interior view of another right valve, hypotype, NYSM 10863. (p. 1109)

23–25—*Ulrichia ventura*, n. sp. Left lateral, ventral and dorsal views of carapace, holotype, NYSM 10864. (p. 1109)

26–29—*Punctomosea cristata* (Swartz & Oriel), n. gen. *26,29*, Right lateral and dorsal views of carapace, hypotype, NYSM 10867. *27*, Left lateral view of another carapace, hypotype, NYSM 10867. *28*, Interior view of right valve, hypotype, NYSM 10868. ×25. (p. 1114)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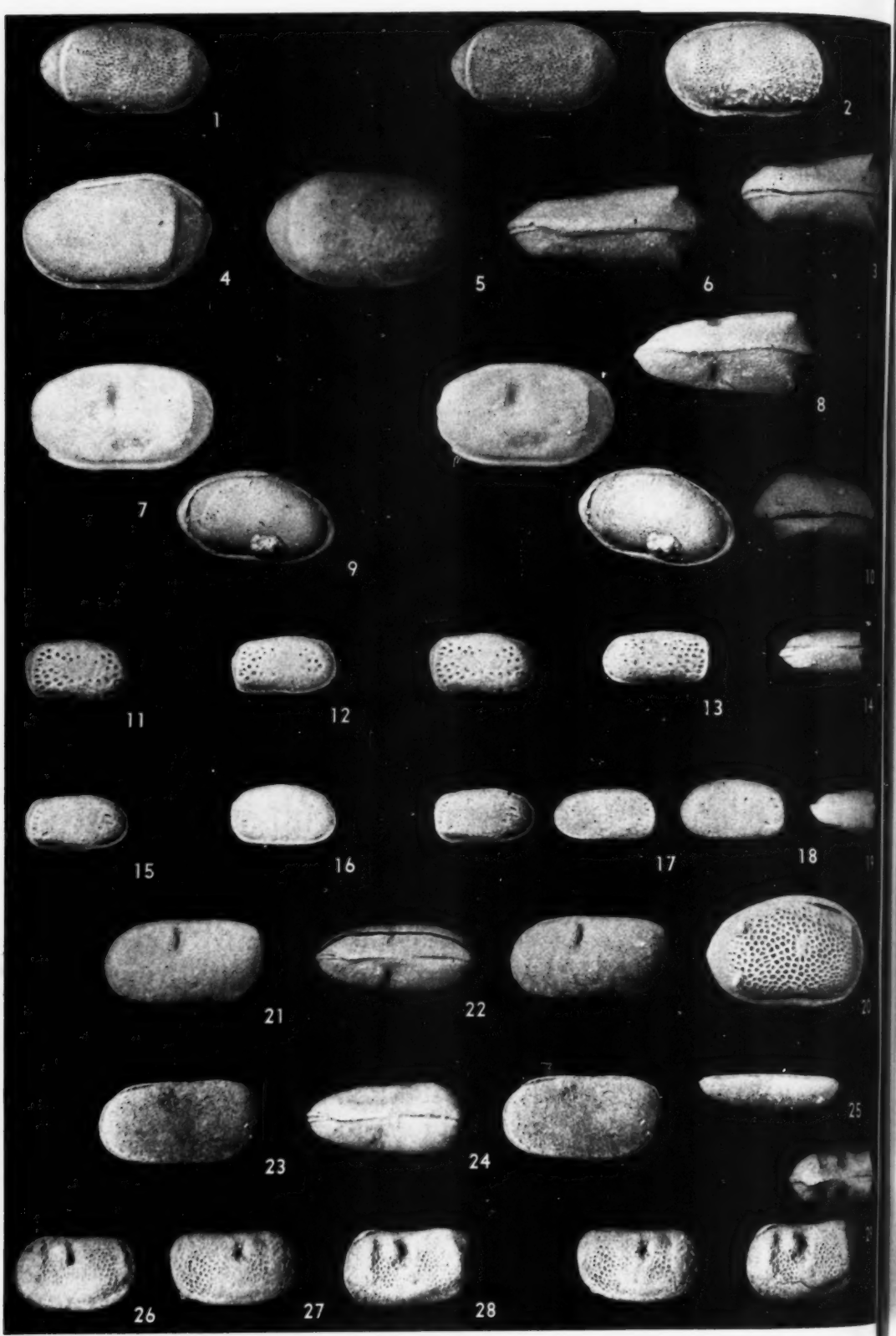
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subreniform rather than nearly triangular in lateral view, and by the anterocentral pits and the more numerous posterior pits.

The anterior cluster of pits may be lacking on one or both valves, but is more often present than not.

Occurrence.—Common at loc. 7 and 5.

Specimens.—Holotype, a carapace, NYSM 10876, loc. 5; paratypes, two carapaces, NYSM 10877, 10878, loc. 7, and another carapace, NYSM 10879, loc. 5.

Genus PONDERODICTYA Coryell & Malkin

Type species: *Cytherella? bispinulatus* Stewart, 1927 (=*Leperditia punctulifera* Hall, 1860). Coryell & Malkin (1936) named *Cytherella? bispinulatus* Stewart, 1927, as the types species. Subsequently Stewart (1936) regarded *Cytherella? bispinulatus* a synonym of *Leperditia punctulifera* Hall.

PONDERODICTYA PUNCTULIFERA (Hall)
Pl. 114, fig. 20

Leperditia punctulifera HALL, 1860, p. 92.
Cytherella? bispinulatus STEWART, 1927, p. 60, pl. 5, fig. 18,19.
Ponderodictya bispinulata CORYELL & MALKIN, 1936, p. 16, fig. 28, 28a, 29–30.
Hamiltonella punctulifera STEWART, 1936, p. 759, pl. 102, fig. 1–5.
Ponderodictya punctulifera KESLING & WEISS, 1953, p. 66–67, pl. 5, fig. 21–29. [A detailed synonymy is presented in this paper.]

Remarks.—This large ostracode is common in the less calcareous shales and is generally associated with *Quasillites* and *Euglyphella numismoides.*

Occurrence.—Common at loc. 3, 7 and 8; rare at loc. 9.

Specimen.—Hypotype, a carapace from loc. 7, NYSM 10884.

Family THLIPSURIDAE Ulrich, 1894
Genus STREPULITES Coryell & Malkin

Type species: By original designation, *Strepulites mooki* Coryell & Malkin, 1936, p. 5, fig. 14.

STREPULITES DIVECTUS, n. sp.
Pl. 115, fig. 4–6

Description.—Carapace large, subhexagonal in dorsal view, reniform in lateral view. Left valve larger than right; overlap conspicuous except along central dorsal border, where the right valve extends above the hinge line. Dorsal margin arcuate; anterior border uniformly rounded; ventral border slightly concave in central part; posterior border narrowly rounded, acuminate centrally. In dorsal view, hinge line slightly S-shaped, depressed just posterior of center. Hinge arcuate, approximately four-fifths as long as the valve. Hingement like that in *Euglyphella* except that the anterior tooth

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EXPLANATION OF PLATE 114

(All magnifications ×30 unless otherwise indicated)

FIG. *1–3—Birdsallella catena*, n. sp. *1*, Right lateral view of carapace, paratype, NYSM 10870. *2,3*, Left lateral and dorsal views of carapace, holotype, NYSM 10869. (p. 1113)

4–6—Birdsallella devonica Coryell & Malkin. Left lateral, right lateral and dorsal views of carapace, hypotype, NYSM 10872. (p. 1113)

7,8—Sulcella emicatusa, n. sp. Left lateral and dorsal views of carapace, holotype, NYSM 10873. (p. 1114)

9,10—Bythocyproidea cf. *B. eriensis* Stewart & Hendrix. Right lateral and dorsal views of carapace, NYSM 10875. (p. 1115)

11–14—Menoeidina multipunctata, n. sp. *11*, Right lateral view of carapace, holotype NYSM 10876. *12,13,14*, Right lateral, left lateral and dorsal views of three carapaces, paratypes NYSM 10877, 10878, 10879. (p. 1116)

15–19—Menoeidina versicula, n. sp. *15,17*, Right and left lateral views of carapace, holotype, NYSM 10880. *16,18*, Right and left lateral views of another carapace, paratype, NYSM 10881. *19*, Dorsal view of carapace, paratype, NYSM 10882. (p. 1115)

20—Ponderodictya punctulifera (Hall). Right lateral view of carapace, hypotype, NYSM 10884. (p. 1117)

21,22—Eukloedenella sp., Left lateral and dorsal views of female carapace, NYSM 10885. Probable outline of male superimposed on fig. 22. ×25. (p. 1110)

23–25—Neokloedenella sp. *23,24*, Left lateral and dorsal views of female carapace, NYSM 10886. *25*, Dorsal view of male left valve, NYSM 10887. ×20. (p. 1111)

26–29—Jonesina apoglypha, n. sp. *26*, Lateral view of left valve, paratype, NYSM 10889. *27*, Lateral view of right valve, paratype, NYSM 10890. *28,29*, Left lateral and dorsal views of female carapace, holotype, NYSM 10888. (p. 1111)

in *Strepulites* is longer, and the intervening area between the teeth is proportionally shorter.

Lateral surface elevated in the central area to form a nearly flat platform. Surface in the anterior and central ventral marginal areas slopes moderately to the free border, anterior slope of right valve steeper; central dorsal area with steep slope. Posterior end of platform set off from the posterior free border by a deeply concave surface. A dorsal longitudinal furrow, open posteriorly at the base of the platform, extends forward and slightly downward to the dorsocentral area, then bends ventrally, terminating at or a little below midheight. Within the posterior half of the platform are two, short, parallel, longitudinal furrows of equal length; both terminate a little anterior to the straight, vertical, crested, posterior edge of the platform. In line with and anterior to the ventral furrow lies a small circular pit. A narrow marginal ridge parallels the anterior half of each valve, but is less developed on the right valve. Posterior one-fourth of each valve with numerous small papillae; rest of surface smooth. A short marginal ridge lies ventrad to the posterior end of the platform.

Measurements.—Greatest length through the dorsal part of the ventral longitudinal furrow; greatest height through the anterior end of the dorsal groove; greatest width central. Dimensions of the holotype are: length, 1.25 mm.; height, 0.70 mm.; width, 0.65 mm.

Remarks.—*Strepulites divectus*, n. sp., resembles *S. tischleri* Coley from the Centerfield limestone of New York, but is distinguished from it by the circular pit anterior to the ventral furrow, the papillated posterior quarter and the two short, parallel, longitudinal furrows of equal length.

Occurrence.—Abundant at loc. 8; common at loc. 7.

Specimens.—Holotype, a carapace, NYSM 10894, loc. 8; paratypes, two left valves, NYSM 10895, 10896, from loc. 8, and a right valve, NYSM 10897, from loc. 7. Specimens NYSM 10896 and 10897 not figured.

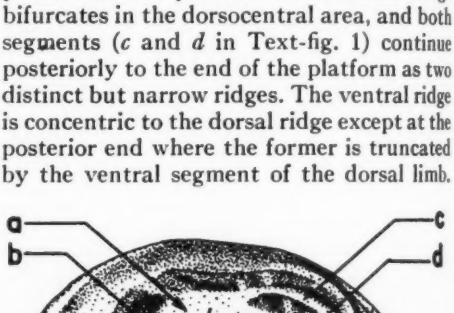
Genus OCTONARIA Jones

Type species: By original designation, *Octonaria octoformis* Jones, 1887, p. 404, pl. 12, fig. 2a,b.

OCTONARIA BIFURCATA, n. sp.
Pl. 115, fig. 7–9; Text-fig. 1

Description.—Carapace hexagonal in dorsal view; reniform in lateral view. Left valve much larger than right, overlap conspicuous along all borders; most pronounced at the ends. Dorsal border arcuate; anterior border unevenly rounded, fullest in ventral half; ventral border concave centrally; posterior border broadly and evenly rounded; left valve grooved to receive the right valve. Hinge approximately half the maximum length of valve; hinge line straight in dorsal and internal views. Hingement like that in *Euglyphella*. Central area of the lateral surface of each valve elevated to form a slightly convex platform.

On left valve, at the base of the posterodorsal wall of the platform is a longitudinal furrow, visible in dorsal view, and subdivided by three or four crossbars. Posterior and dorsal walls of platform abruptly elevated; anterior marginal surface slopes moderately to the free border; ventral marginal surface moderately steep anteriorly, but gradually increases in steepness posteriorly. The surface of the platform is crossed by deep furrows separated by two crescentic ridges (*a* and *b* in Text-fig. 1) which are convex dorsally in the anterior portion of the platform. The dorsal ridge bifurcates in the dorsocentral area, and both segments (*c* and *d* in Text-fig. 1) continue posteriorly to the end of the platform as two distinct but narrow ridges. The ventral ridge is concentric to the dorsal ridge except at the posterior end where the former is truncated by the ventral segment of the dorsal limb.



TEXT-FIG. 1—*Octonaria bifurcata*, n. sp. Exterior view of left valve, ca. ×60. *a*, dorsal ridge; *b*, ventral ridge; *c,d*, dorsal and ventral segments of the dorsal ridge. Drawing prepared from enlarged photograph of specimen shown on Pl. 115, fig. 8.

The furrows are subdivided by numerous crossbars; the dorsal furrow has four or five crossbars, the central and ventral furrows with three to five crossbars, and the furrow between the bifurcated portion of the dorsal ridge has two crossbars. The crossbars are unevenly spaced, vary in width and height, and may be perpendicular or oblique to the ridges. A small recess occurs beneath the posterior end of the platform where the vertical bounding ridge projects beyond the posterior platform wall. A narrow flange or marginal ridge set off by a groove margins the dorsal and free borders except in the central ventral area.

The smoothly rounded platform of the smaller right valve roughly parallels the outline of the valve. Ridges, furrows and crossbars on the platform are like those on the left valve except that the dorsal segment of the bifurcated dorsal ridge is little more than an oblique crossbar that meets the dorsal bounding ridge slightly posterior of center. The right valve also has the posterior recess and marginal ridge like the left valve, but both are less well developed. This valve lacks the central dorsal furrow at the base of the platform.

Measurements.—Greatest length midway between dorsal and ventral borders; greatest height located at approximately one-third the length from the anterior end; greatest width through the anterior end of the platform. Dimensions of a typical carapace are: length, 0.81 mm.; height, 0.50 mm.; width, 0.41 mm.

Remarks.—The diagnostic features of *Octonaria bifurcata*, n. sp., which differentiate if from *O. quadricostatus* Van Pelt from the Traverse group of Michigan are: (1) the two concentric ridges on the right valve, (2) the greater arcuation of the ridges on the left valve and (3) a longer dorsal ridge also present on the left valve. As compared to *O. crescentiformis* Van Pelt, also from the Traverse group, *O. bifurcata* is less elongate, has a bifurcation of the dorsal crescentic ridge and the ventral furrow below the ventral ridge is always present.

The small crossbars which subdivide the furrows are frequently obscured by rock matrix adhering to the valves. However, the major ridges are usually sufficiently well defined to make identification possible. No major variation in the ornamentation or size of the specimens was observed.

Occurrence.—Extremely abundant at loc. 7; rare at loc. 8 and 9.

Specimens.—Holotype, a carapace, NYSM 10898; three paratypes, a right valve, NYSM 10901, and two left valves, NYSM 10899, 10900. All types from loc. 7. Specimens NYSM 10900 and 10901 not figured.

Family BAIRDIIDAE Sars, 1887
Genus BAIRDIA McCoy

Type species: By original designation, *Bairdia curtua* McCoy, 1884, p. 164, pl. 23, fig. 6.

BAIRDIA SUMMACUMINATA Coryell & Malkin
Pl. 115, fig. 10,11

Bairdia summacuminata CORYELL & MALKIN, 1936, p. 9, fig. 23.

Remarks.—In ventral view the adult carapaces in this collection show an unusual, nearly elliptical depression midway along the ventral border. On some specimens the depression is rimmed laterally by faint ridges that may be seen in lateral view. The ridge on the left valve is usually the better developed. This feature is also present on the holotype. The amount of overlap along the dorsal border in the average specimen is considerably less than is illustrated by Coryell & Malkin (1936, p. 12, fig. 23).

Occurrence.—Abundant at loc. 8; common at loc. 7.

Specimens.—Hypotypes, two carapaces, NYSM 10902, 10903, from loc. 8.

Genus BYTHOCYRPRIS Brady

Type species: *Bairdia basquetiana* Brady, 1866, p. 364 (=the young of *Bythocypris reniformis* Brady, 1880).

BYTHOCYPRIS LUCASENSIS Stewart
Pl. 115, fig. 13,14

Bythocypris lucasensis STEWART, 1936, p. 775, pl. 101, fig. 17; STEWART & HENDRIX, 1945b, p. 111, pl. 12, fig. 15,16.

Occurrence.—Abundant at loc. 7, rare at loc. 3, 5, 6, 8 and 9.

Specimens.—Hypotypes, two carapaces from loc. 7, NYSM 10905, 10906.

BYTHOCYPRIS SUBQUADRATA Stewart
Pl. 115, fig. 12

Bythocypris subquadrata STEWART, 1936, p. 755,

pl. 101, fig. 18,19; KESLING & WEISS, 1953, p. 56, pl. 5, fig. 1–3.

Occurrence.—Rare at loc. 5, 7 and 8.

Specimen.—Hypotype, a carapace, NYSM 10904, from loc. 7.

BYTHOCYPRIS TRANSPTYXIS, n. sp.
Pl. 115, fig. 15,16

Description.—Carapace large, subovate to subtriangular in lateral view. Left valve larger than right, overlap conspicuous along all margins. Dorsal border arcuate, posterior border with long, nearly straight dorsal slope, unevenly rounded in ventral half; anterior border with less steep dorsal slope, narrowly rounded anteroventrally; ventral border straight, flattened centroventrally; hinge line gently curved. Hingement not observed.

Lateral surface convex, somewhat compressed adjacent to antero- and posteroventral borders; left valve more inflated than right. In end views, the overlap margin is straight in the ventral half, oblique in the dorsal half, curved to meet the arcuate hinge line. All surfaces smooth. On the surface of some specimens, especially the light-colored ones, are pin point-like dots that may be the loci of pore canals or a similar shell structure.

Measurements.—Greatest length one-third the distance from the ventral border; greatest height and width central. Dimensions of the holotype are: length, 1.38 mm.; height, 0.90 mm.; width, 0.62 mm.

Remarks.—This new species may be distinguished from *Bythocypris devonica* Ulrich from the Bryozoa bed at the Falls of the Ohio by the flattened central ventral border of the left valve which strongly overlaps the right valve in that area, the more triangular outline in lateral view, and the curved contact margin in the dorsal half.

Occurrence.—Abundant at loc. 8; common at loc. 7; rare at loc. 9.

Specimens.—Holotype, a carapace, NYSM 10907, loc. 7; paratypes, two carapaces, one from loc. 7, NYSM 10908, and one from loc. 8, NYSM 10909. Specimens NYSM 10908 and 10909 not figured.

BYTHOCYPRIS TRANSPTYXIS var. TRUNCATA, n. var.
Pl. 115, fig. 17,18

Description.—Several carapaces differ from the typical form of *Bythocypris transptyxis* by having a truncated dorsal border, a shorter posterodorsal slope and a nearly vertical anterior border in the ventral half. Consequently, the anteroventral corner is more narrowly rounded in the variant. Also the overlap along the posteroventral border is lacking or poorly developed in *B. transptyxis* var. *truncata*.

Measurements.—Greatest length a little ventrad of midway between the dorsal and ventral borders; greatest height and width central. Dimensions of the holotype are: length, 1.25 mm.; height, 0.89 mm.; with, 0.62 mm.

Occurrence.—Common at loc. 8, rare at loc. 7.

Specimens.—Holotype, a carapace, NYSM 10910, loc. 8.

BYTHOCYPRIS PHASEOELLA, n. sp.
Pl. 115, fig. 19,20

Description.—Carapace medium sized, reniform, elongate in lateral view; lanceolate in dorsal view. Left valve larger than right, overlap noticeable except along dorsal border. Dorsal border straight, short; anterior border with long, dorsal slope, narrowly rounded in ventral half; ventral border straight or concave centrally. Hinge line irregular; in dorsal view it extends diagonally forward from the posterior corner, terminating aginst a prominent overlapping flap along the anterodorsal border. All surfaces smooth. Hingement not observed.

Measurements.—Greatest length approximately one-third distance from ventral border; greatest height slightly anterior of center; greatest width one-quarter distance from posterior end. Dimensions of the holotype are: length, 1.06 mm.; height, 0.52 mm.; width, 0.41 mm.

Remarks.—*Bythocypris phaseoella*, n. sp. is more elongate, has a steeper anterodorsal slope and is larger than *B. lucasensis* Stewart, from the Silica shale of Ohio.

Occurrence.—Abundant at loc. 8; common at loc. 7, and rare at loc. 9.

Specimens.—Holotype, a carapace, NYSM 10911, from loc. 8; paratype, another carapace, NYSM 10912, from loc. 8.

BYTHOCYPRIS TUBERCULA, n. sp.
Pl. 115, fig. 21,22

Description.—Carapace of medium size, reniform in lateral view, ovate in dorsal

view. Dorsal border arcuate; ventral border straight or gently curved; anterior border narrowly rounded subcentrally; anterodorsal border long and gently inclined; posterior border broadly rounded, obtusely pointed centrally. Left valve larger than right, overlapping all the way around; overlap most conspicuous along dorsal and midventral borders.

Both valves moderately convex, fullest posteriorly. A small blunt, low swelling is present just inside the posteroventral corner. Surface smooth.

Measurements.—Greatest length approximately midway between dorsal and ventral border; greatest height slightly anterior of center; greatest width in posterior half. Dimensions of the holotype are: length, 1.02 mm.; height, 0.58 mm.; width, 0.42 mm.

Remarks.—*Bythocypris tubercula*, n. sp., resembles *B. lucasensis* Stewart, but differs from the latter by having a more arcuate dorsal margin, a low inconspicuous swelling near the posteroventral corner, more acuminate anterior and posterior borders and the new species is larger.

Occurrence.—Common at loc. 7.

Specimens.—Holotype, a carapace, NYSM 10913; paratype, another carapace, NYSM 10914, both types from loc. 7.

Family HEALDIIDAE Harlton, 1933
Genus HEALDIA Roundy

Types species: By original designation, *Healdia simplex* Roundy, 1926, p. 8, pl. 1, fig. 11a–c.

HEALDIA cf. H. ARKONENSIS
Coryell & Malkin
Pl. 116, fig. 1–3

[cf.] *Healdia arkonensis* CORYELL & MALKIN, 1936, p. 14, fig. 25.

Remarks.—Several small specimens which resemble *Healdia arkonensis* from the Wickler beds, Ontario, are believed to be instars of that species. They differ from the adult by not having the dorsal and ventral extremities of the posterior ridge drawn out into distinct spines. In addition, the ridge itself is convex posteriorly, except in its dorsal part, rather than concave posteriorly as in the adult. Dimensions of the instars compared to the adult are (mm.):

	length	height	width
Instars	0.67	0.42	0.31
Adults	0.91	0.54	—

Occurrence.—Common at loc. 8; rare at loc. 1 and 7.

Specimens.—Hypotypes, two carapaces, NYSM 10920, 10922, from loc. 7, and a left valve from loc. 8, NYSM 10921.

Family QUASILLITIDAE Coryell & Malkin, 1936, emend. Henningsmoen, 1953

Remarks.—The Quasillitidae as defined by Henningsmoen (1953) consists essentially of the Ropolonellidae and Quasillitidae of Coryell & Malkin (1936). In all of the genera, the carapace is inequivalved, with the left valve larger than the right. The dominant ornamentation pattern is the so-called *Bufina*-pattern, consisting of a ridge at the anterior end and a pair of spines at the posterior end of each valve. This pattern is modified in different ways, and is often obscured by other features of ornamentation as in *Euglyphella*, or may be greatly reduced as in *Rudderina*.

Within the genera currently assigned to the Quasillitidae and occurring in the Windom shale, all except *Lucasella* are abundant, and in both number of species and specimens, make up the bulk of the fauna. Species of *Euglyphella* are readily separated, one from the other, and specific limitations are precisely defined. Such is not the case in *Jenningsina*, *Quasillites*, *Bufina* and *Parabufina*. Five species of *Quasillites* are reported to occur in the Windom shale, but the limits of these species are extremely difficult to define.

A brief study of a large collection of adult specimens of *Quasillites* revealed that the criteria cited by the different original authors as a basis for specific differentiation was unsatisfactory. Many specimens possess characteristic features ascribed to two or more species. Furthermore, the larger the number of specimens studied, the more difficult it became to retain old or set up new specific limitations. It was found, however, that most of the specimens from the Windom shale can be separated quickly and easily into two main types, within which there is considerable individual variation. These types are described under the specific names *Quasillites subobliquus* and *Q. angulatus*. Another type was also recognized, but it is quite rare, being found at only two localities. It was apparent from this study that differences regarded as significant and

used as a basis for specific determination in small collections may prove to be individual variations when large collections are available. Undoubtedly, the type of preservation influences and may even alter certain structural and ornamental features of the carapace. In general, calcareous specimens that have been replaced by secondary calcite or pyrite, and in some cases by silica, are more coarsely ridged and the finer details of hingement and of lateral and marginal surface features are often destroyed.

An examination of numerous immature specimens has led the writer to suspect that some species have been formulated on instars, whereas the adults of those species are described under a different name. From the collection of adult specimens it was also learned that some species appear to possess two forms which are identically ornamented, but differ in the proportions of the carapace. It has not been determined whether or not this size difference within a species is an expression of dimorphism.

It is hoped that future studies concerned with the ontogeny of *Quasillites* will indicate if this genus is dimorphic, and perhaps reveal more concrete features upon which specific assignments can be erected. Until such time, it is advisable to use extreme care when setting up new species of *Quasillites*, especially when only a few specimens are available. Similar caution should also be exercised with *Bufina*, *Parabufina* and *Jenningsina*, although species of those genera apparently display less individual variation than *Quasillites*.

Genus JENNINGSINA Coryell & Malkin

Type species: *Graphiodactylus catenulatus* VAN PELT, 1933, by original designation of Coryell & Malkin, 1936, p. 19.

JENNINGSINA CATENULATA (Van Pelt)
Pl. 116, fig. 16–26

Graphiodactylus catenulatus VAN PELT, 1933, p. 333, pl. 39, fig. 31,32.
Jenningsina catenulata CORYELL & MALKIN, 1936, p. 20, fig. 35.
Jenningsina divaricata SWARTZ & ORIEL, 1948, p. 561, pl. 79. fig. 24,
Jenningsina catenulata KESLING & WEISS, 1953, p. 62, pl. 4, fig. 40,41, 44–49.

Supplementary description.—Carapace small, subrectangular to subreniform in lateral view, subtriangular in ventral and dorsal views. Dorsal margin arcuate to nearly straight; ventral margin concave centrally; anterior margin unevenly rounded, radius of curvature less in ventral half; posterior margin broadly rounded to nearly vertical. Left valve larger than right, overlap noticeable. Hinge line gently curved. Hinge straight; flange of right valve received by groove in left valve.

In the anteroventral portion of each valve a small crescent-shaped flange lies outside the free edge. Entire free border of left valve margined by a narrow ridge; central ventral portion of ridge absent on right valve. Ridges on lateral surface less divergent in more elongate forms.

Measurements.—In typical specimens, greatest length through central pit; greatest height one-fourth distance from anterior end; greatest width between posterior ridges. Length, 0.64 mm.; height, 0.36 mm; width, 0.29 mm.

Remarks.—Examination of over two hundred beautifully preserved specimens reveals that *Jenningsina catenulata* (Van Pelt) is extremely variable in general outline and proportions of valves. Specimens vary in shape from narrow, elongate forms in which the dorsal and ventral borders are nearly parallel to short, compact forms in which the dorsal and ventral borders are strongly divergent anteriorly. The majority of specimens fall between the two extremes, hence they are the more characteristic of the species.

The specimen classified as *Jenningsina divaricata* by Swartz & Oriel (1948) is a favorable example of the shorter, more compact end member and is here referred into synonymy.

Occurrence.—Extremely abundant at loc. 7 and 8; common at loc. 9; rare at loc. 4 and 5.

Specimens.—Hypotypes, from loc. 7, ten carapaces, NYSM 10934–10943.

Genus SCALPTINA, n. gen.

Type species: *Scalptina incuda*, n. sp.

Description.—Carapace small, subpyriform to subreniform in lateral view, subretangular in dorsal view. Left valve slightly larger than right. Lateral surface with low, arcuate ridge close to the anterior border and a smaller subvertical ridge near the posterior border. Surface ornamented with

coarse, irregular reticulations except for small circular bald spot near the center of each valve. Marginal areas smooth. Hinge line straight, slightly depressed, and approximately three-fifths as long as the valve.

Remarks.—*Scalptina*, n. gen., resembles *Jenningsina* Coryell & Malkin in size and shape, but differs from it by having reticulations rather than fine ridges and crossbars, a smooth central spot instead of a pit and by lacking an anteroventral flange.

SCALPTINA INCUDA, n. sp.
Pl. 116, fig. 27–30

Description.—Carapace small, subreniform in lateral view, subrectangular in dorsal view. Dorsal border gently arched centrally; ventral border concave centrally; anterior border nearly evenly rounded; posterior border broadly rounded, greatest extension in dorsal half. Hinge line straight, depressed. Hinge approximately three-fifths as long as the valve. Left valve larger than right.

Anterodorsal corner raised slightly above the hinge line. Lateral surface convex, abruptly elevated posteriorly to form subvertical to vertical ridge. Posterior slope of ridge convex, steep. Slightly posterior to the anterodorsal border another ridge extends from the anterior corner to the central anterior area, becoming obsolete ventrally. Surface depressed immediately posterior to anterior ridge. Anterior slope moderately steep on left valve, steeper on right valve. Ventral marginal area moderately steep anteriorly, gradually steepens posteriorly until it is nearly perpendicular ventrad to the posterior ridge. Dorsal marginal area gently rounded. Lateral surface, exclusive of marginal areas, covered by coarse reticulations which tend to be concentric with the outline of the valve except posteriorly, where the reticulations terminate against the posterior ridge. Central area gently inflated; summit marked with circular, unornamented area. Marginal areas smooth. Anterior margin with small marginal ridge, generally less prominent on the right valve.

Anterior cardinal angle approximately 140°; posterior cardinal angle approximately 125°.

Measurements.—Greatest length through median spot; greatest height through anterior ridge; greatest width through center. Dimensions of a typical carapace are: length, 0.56 mm.; height, 0.32 mm.; width, 0.24 mm.

Occurrence.—Common at loc. 7.

Specimens.—Holotype, a carapace, NYSM 10945; paratypes, two carapaces, NYSM 10944, 10947, and a left valve, NYSM 10946; all types from loc. 7.

Genus PROSOPEIONUM, n. gen.

Type species: *Prosopeionum plexum*, n. sp.

Description.—Carapace of moderate size, subrhomboidal to subelliptical in lateral view, subhexagonal, elongate in dorsal view. Left valve larger than right, overlap conspicuous. Hinge line straight, depressed in posterior half. Bisulcate. L2 knoblike, well defined. Surface of valves reticulated and/or papillated, marginal areas less ornamented. Valves with unornamented median spot and with a spine near the posteroventral corner. Anterior and posterior marginal slopes moderately steep to abrupt.

Remarks.—This genus resembles *Quasillites* in general outline, form and overlap relationships; in fact, in outline, the right and left valves of the two genera are nearly identical. Other common features include the posteroventral spine, the median circular spot, and the occasional anteroventral margin tubercles. *Prosopeionum* can be readily separated from *Quasillites* by the evident subhemispherical L2, the deep sulci, and the distinctly different ornamentation pattern.

PROSOPEIONUM PLEXUM, n. sp.
Pl. 116, fig. 31–37

Description.—Carapace subrhomboidal in lateral view, subhexagonal, elongate in dorsal view, subrectangular in anterior view, subcircular in posterior view. Left valve larger than right; overlap most conspicuous along ventral border. Dorsal border of left valve gently arched in posterior three-fourths, anterior one-fourth with hump; dorsal border of right valve gently arched. Ventral border of carapace straight or slightly concave in the center; anterior border subevenly rounded, fullest in ventral half; posterior border unevenly, broadly rounded with greatest extension in dorsal half and definite swing. Hinge line straight, posterior half invaginated. Left valve grooved to receive right valve.

Bisulcate; S1 short, deep and arcuatel extends from a little below the dorsa, border to approximately midheight. S2 smaller, shorter and shallower than S1, and begins well below the dorsal border. S1 convex anteriorly and is located about one-third the distance from the anterior end; S2 convex posteriorly, situated midway between anterior and posterior ends. Both sulci well defined.

L1 a prominent ridge abruptly elevated dorsally and anteriorly, confluent with lateral surface ventrally and posteroventrally. L2 of medium size, round, extending from dorsal border to midheight, bounded laterally by S1 and S2 and ventrally confluent with the lateral surface.

Posterior half of valves gently inflated, fullest posterodorsally. Anteroventral and posterior marginal slopes moderately steep; posterodorsal and ventral marginal slopes less steep. Elevated portion of lateral surface marked with delicate network of fine ridges and reticulations. Superimposed on the network are numerous papillae of various sizes. Marginal slopes are smooth or with a few scattered papillae; marginal tubercles occasionally present along anteroventral border.

A short, blunt spine, directed downward and backward lies a little inside the posteroventral corner. Located centrally and merging with the posteroventral surface of L2 is a circular spot which is probably the external expression of adductor muscle scar. The spot is either smooth or crossed by very faint ridges. On some specimens the free edge of the contact border is raised to form a narrow, marginal ridge which extends partially or completely around the free border.

Measurements.—Greatest length through central spot; greatest height through L1 on left valve, essentially uniform between dorsal and ventral borders of right valve; greatest width through posterocentral area. Dimensions of a typical adult specimen of each form are given below (mm.):

	length	height		width
		right valve	left valve	
narrow form	1.33	0.74	0.65	0.57
short form	1.30	0.78	0.68	0.65

Remarks.—*Prosopeionum plexum*,, n. sp., apparently has two forms which are found together and, except for their dimensions, are identical. The narrower forms are more common. Whether or not the forms are sex dimorphs has yet to be established. A similar phenomenon has also been observed in *Quasillites*.

The instars of *Prosopeionum plexum* have the posterior end noticeably less high than the anterior end.

Occurrence.—Common at loc. 7, rare at loc. 8 and 9.

Specimens.—Holotype, a carapace, NYSM 10948; paratypes, three adults carapaces, NYSM 10949–10951, an adult right valve, 10954, and 2 immature carapaces, NYSM 10952, 10953. Type specimens from loc. 7.

Genus QUASILLITES Coryell & Malkin

Types species: By original designation, *Quasillites obliquus* Coryell & Malkin, 1936, p. 18, fig. 36–36a.

QUASILLITES ANGULATUS Smith
Pl. 117, fig. 13–25

Quasillites cf. *Q. lobatus* SWARTZ & ORIEL, 1948, p. 556–557, pl. 80, fig. 19.
Quasillites angulatus SMITH, 1956, p. 4, pl. 1, fig. 12–15.

Remarks.—This species adequately illustrates the degree of individual variation that may be expected in species of *Quasillites*. A brief description covering the more salient features of ornamentation and outline is presented below. This is followed by comparisons designed to show the extremes of individual variation that occur in particular features. This pattern is also used in the discussion of *Q. subobliquus*.

The average specimen has coarse ridges on the lateral surface which are only slightly divergent in the posterior half of the valve; an anterodorsal swelling is present and ventrad to the swelling is a short, blunt spine which projects backward and outward. At the anterior end a U-shaped ridge is situated just inside the anterior border. The anterior slope of the ridge is moderately steep, and posteriorly adjacent to the anterior ridge is a faint shallow depression which is best expressed in the dorsal half. A medium sized smooth spot occupies the central part of the lateral surface. The carapace is subrhomboidal in lateral view; the anterodorsal margin is raised above the hinge line to form a small hump and the anterior border

is usually interrupted at midheight by a small cusp. The ventral border is slightly concave centrally.

The specimens described above grade into others which retain the coarse ridges, and have a more prominent posterodorsal swelling and anterior ridge. The depression posterior to the anterior ridge is deeper and better defined, and the central smooth spot tends to be larger. The lateral ridges immediately dorsad from the smooth spot are either much finer than on the rest of the carapace or absent. The posteroventral spine projects backward, but only slightly outward. The lateral outline is nearly the same, except that the small cusp is occasionally lacking and the ventral central concavity is greater.

Gradations in the opposite direction also occur: some specimens retain the coarse ridges, but have the anterior ridge and the posterodorsal swelling greatly subdued. There is only a slight indication in the anterodorsal area of a depression adjacent to the anterior ridge, and the anterior slope is more rounded. The central unornamented spot tends to be smaller, although this is variable. The central dorsal area has well defined ridges. Furthermore, the posteroventral spine projects backward and slightly more outward. In lateral view, the posteroventral border is a little more oblique; the cusp is nearly always present along the anterior border and along the ventral border the central concavity is weakly developed, or absent.

Several specimens, which possess the necessary features to be included in one of the members described above, were found to differ from the majority of the specimens within that group by having a more elongate outline and a narrower carapace. These specimens are tentatively retained in this species on the basis that they could conceivably be sex dimorphs.

Taken collectively, the features described above most closely fit the specific description of *Quasillites angulatus* Smith. By virtue of the previous description it is likely that some of the specimens referred by Swartz & Oriel to *Q. lobatus* would also be included in *Q. angulatus*. However, because their material consisted of pyritized and silicified specimens, many of the details of ornamentation necessary for specific determination are destroyed, and direct comparison with calcareous specimens is difficult.

Occurrence.—Abundant at loc. 1, 5, 7 and 8; common at loc. 9; rare at loc. 2, 4, 6.

Specimens.—Hypotypes, 2 carapaces from loc. 5, NYSM 10964, 10969; 4 carapaces, NYSM 10963, 10965, 10968, 10970, and 2 left valves, NYSM 10966, 10967, and a right valve, 10971, from loc. 7.

QUASILLITES SUBOBLIQUUS Swartz & Oriel

Pl. 117, fig. 1–12

Quasillites subobliquus SWARTZ & ORIEL, 1948, p. 559, pl. 80, fig. 10.

Remarks.—This species is typified by specimens which have fine lateral ridges with numerous delicate crossbars in the furrows. The lateral ridges are essentially parallel to the dorsal and ventral borders in the posterior half of the carapace, except in the central posterior area, where the ends of the ridges tend to curve downward. In the anterior half, the lateral ridges are arranged concentrically around a tight U-shaped inner loop. The axis of the loop passes through the anteroventral corner and the smooth central spot, and makes an angle of from 25° to 35° with the logitudinal axis of the carapace. The anterior U-shaped ridge and the posterodorsal swelling are usually poorly expressed. In most specimens the root of a short, blunt, posteroventral spine lies directly ventrad or a little anterior to the ill-defined posterodorsal swelling. In lateral view, the carapace is subrhomboidal with nearly parallel dorsal and ventral borders and the extremities are less oblique than *Quasillites obliquus* Coryell & Malkin. The anterior border forms a smooth arc, uninterreputed by cusps, denticles or papillae. The smooth central spot is generally less prominent than in *Q. angulatus* Smith.

The typical and most abundant specimens grade into forms that have a more noticeable anterior ridge, a larger central unornamented spot and slightly coarser lateral ridges. In lateral view, the posterior border is less oblique and the height of the carapace increases slightly. In addition the axis of the concentric ridges in the anterocentral part of the valves generally makes a smaller angle with the longitudinal axis of the carapace.

Gradation also occurs in the opposite direction; the most significant change is in the shape of the carapace which becomes more rhomboidal and less high; hence the carapace appears more elongate and more oblique. In addition, the central ventral concavity is less. The anterior ridge and posterodorsal swelling are very poorly expressed, but the posteroventral spine generally projects outward more than in typical specimens.

In practically all of the specimens, the anterior ridge is better developed on the smaller right valve.

The chief characteristics of the specimens described above agree most closely with the features noted for *Quasillites subobliquus* Swartz & Oriel. Again, direct comparison with the holotype is difficult because of the difference in preservation.

Quasillites subobliquus differs from *Q. angulatus* by having finer lateral ridges, a less oblique outline, and by lacking an anterocentral cusp. In general, in *Q. angulatus* the posterodorsal swelling is more pronounced and the anterior cardinal area of the left valve is raised to form a hump.

Occurrence.—Abundant at loc. 6 and 8; common at loc. 4, and 5; rare at loc. 1, 2, 3 and 7.

Specimens.—Hypotypes, three carapaces from loc. 8, NYSM 10955, 10957, 10962; 4 carapaces, NYSM 10956, 10958, 10960, 10961, and a left valve, NYSM 10959, from loc. 6.

QUASILLITES sp.
Pl. 117, fig. 26–28

Description.—Carapace subrectangular in lateral view. Left valve larger than right, overlap most conspicuous along ventral and anterior borders. Hinge line straight, depressed in posterior half of valve. Dorsal border of left valve straight, anterior border unevenly rounded, radius of curvature less in ventral half, dorsal half of anterior border nearly straight; ventral border straight or with very gentle concavity in central ventral area; posterior border unevenly rounded, radius of curvature less in dorsal half. Valve with moderate posterior swing. Right valve with arcuate dorsal border; anterior border nearly evenly rounded; ventral border straight; posterior border unevenly rounded, greatest extension in dorsal half. A relatively broad marginal flange parallels the anterior border of the right valve, a less well developed flange present on left valve.

Lateral surface ornamented with distinct narrow ridges; ridges in the anterior half are roughly concentric to a larger, more prominent ridge situated just inside the anterior border. In the posteroventral area the ridges are parallel to the ventral border, whereas those in the posterodorsal area are slightly convex. The furrows between the ridges commonly have delicate crossbars. A round, unornamented spot lies slightly anterior of center and a short, blunt, posteroventral spine projects obliquely outward and backward. Small marginal denticles occur along the anteroventral margin. Lateral surface with a poorly defined depression in the anterodorsal area. Marginal areas smooth.

Measurements.—Greatest length approximately midway between dorsal and ventral borders; greatest height of right valve about one-fourth the distance from the anterior end; greatest height of right valve a little posterior of center; greatest width through the posterior half. Dimensions of a carapace are: length 1.25 mm.; height, 0.71 mm.; width, 0.56 mm. Height of a right valve, 0.61 mm.

Remarks.—The specimens described above resemble *Quasillites jubatus* Kesling & Weiss from the Norway Point formation of Michigan by having marginal denticles. They differ by having finer lateral ridges not arranged in a whorl-like pattern, a greater posteroventral swing to the carapace, and a more elongate carapace.

Because only a few specimens were found, the limitations of the species are not known, and it is deemed better to recognize the specimens as *Quasillites* sp. until additional specimens are available so that a more critical evaluation can be made.

Occurrence.—Rare at loc. 5 and 6.

Specimens.—A carapace, NYSM 10972, and a right valve, NYSM 10973, from loc. 5.

Genus BUFINA Coryell & Malkin

Type species: By orginal designation, *Bufina elata* Coryell & Malkin, 1936, p. 8.

BUFINA BICORNUTA (Ulrich)
Pl. 118, fig. 1–5

Moorea bicornuta ULRICH, 1891, p. 191–192, pl. 16, fig. 4a-c; GRABAU, 1898–99, p. 310, fig. 253.
Bufina bicornuta WARTHIN, 1945, card 71.

Remarks.—This species was found at all localities except locality 3 and is represented by from eight to forty specimens at each locality. At each locality the specimens range in size from slender, elongate forms to comparatively short, stubby, obese forms. The ornamentation, including the two posterior spines, the anterior crescent shaped ridge and the marginal papillae, is extremely variable. However, the ventral spine is always more posterior than the dorsal one, but the latter tends to be slightly larger. On a basis of shape, it is usually possible to trace an uninterrupted series from elongate forms through intermediate forms to short forms.

Occurrence.—Abundant at loc. 7 and 8; common at loc. 1, 2, 4, 5, 6 and 9.

Specimens.—Hypotypes, a carapace, NYSM 10980, from loc. 5; 2 carapaces, NYSM 10979, 10982, and a right valve, NYSM 10981, from loc. 7.

Genus PARABUFINA Smith

Type species: By original designation, *Parabufina convexa* Smith, 1956, p. 5.

PARABUFINA SUBOVALIS (Swartz & Oriel)
Pl. 118, fig. 6–11

Condracypris subovalis SWARTZ & ORIEL, 1948, p. 565, pl. 81, fig. 9.

Supplementary description.—Carapace medium sized, inequivalved. Carapace subovate in lateral view. Dorsal border of left valve straight, anterior border evenly rounded, ventral border gently covex with slight concavity in the central ventral area, posterior border unevenly rounded, radius of curvature less in dorsal half. Height of valve much greater at anterior end. Dorsal border of right valve gently convex, anterior and posterior borders evenly rounded, ventral border slightly convex to straight. Left valve larger than right; overlap most conspicuous along the ventral and anterior margins. Hinge line depressed, straight in dorsal view; anterior and posterior cardinal areas of the left valve with small overlapping processes, anterior process larger than posterior process.

Lateral surface gently convex; smooth, finely granular or pitted, ornamented by a sharp-crested ridge near the extremities of each valve. Anterior ridge vertical, projects outward and forward; posterior ridge inclined posteroventrally, projects outward and backward. There is a tendency for the anterior ridge on the left valve to be weakly developed. In some specimens this ridge is expressed by a low, rounded swelling.

Ventral half of the free contact margin ornamented with a row of papillae on each valve. The rows of papillae may be complete, interrupted or absent on one or both valves. In interior view, the left valve has prominent, arcuate sockets at each end of the hinge line which receives teeth from corresponding postions on the right valve. Hingement between the sockets and teeth consists of flange and groove arrangement.

Measurement.—Greatest height approximately one-fourth the length from the anterior end; greatest length approximately midway between the dorsal and ventral borders; greatest width, exclusive of ridges, slightly posterior of center. Dimensions of a typical carapace are: length, 0.83 mm.; height, 0.56 mm.; width, 0.44 mm.

Remarks.—*Parabufina convexa* can be separated from *P. subovalis* on the basis of shape; *P. subovalis* is more ovate, has a greater inequality at the extremities and tends to be less convex along the ventral border.

Occurrence.—Abundant at loc. 7, common at loc. 1, 2 and 8, rare at loc. 5 and 9.

Specimens.—Hypotypes, 2 carapaces, NYSM 10987, 10988, three left valves, NYSM 10983, 10984, 10986, and right valve NYSM 10985; all from loc. 7.

PARABUFINA CONVEXA Smith
Pl. 118, fig. 12–14

Parabufina convexa SMITH 1956, p. 4–5, pl. 1, fig. 16–18.

Remarks.—This species also shows a tendency to have the anterior ridge on the left valve underdeveloped.

Occurrence.—Common at loc. 1, 2, 5, 7 and 8; rare at loc. 3, 4, 6, and 9.

Specimens.—Hypotypes, a carapace, NYSM 10991, a left valve, NYSM 10990, and a right valve, NYSM 10989, all from loc. 7.

Genus LUCASELLA Stewart

Type species: By orginal designation, *Lucasella mundula* Stewart, 1936, p. 761.

? Lucasella spinulifera Stewart
Pl. 118, fig. 15,16

[?] *Lucasella spinulifera* Stewart, 1936, p. 761–762, pl. 102, fig. 20,21.

Remarks.—A small, well preserved carapace and a right valve tentatively identified as *Lucasella spinulifera* have a row of marginal papillae along the anteroventral border not shown on the holotype. Both specimens differ further from the ones from the Silica shale by having a more ovate outline, and the carapace has a less recessed hinge line in the posterior half. However, the anterodorsal and two posterior spines are well developed and the larger left valve overlaps the smaller right valve along the entire free border. Because only two specimens were found, the limitations and variations of the species cannot be defined. The writer suspects that this species would be placed more correctly in the family *Quasillitidae*. The close similarity of this form with *Bufina* and *Parabufina* in outline, overlap relationships, marginal ornamentation and surface ornamentation is apparent.

Occurrence.—Rare at loc. 7.

Specimens.—Hypotype, a carapace, NYSM 11003, from loc. 7.

Genus Euglyphella Warthin

Types species: *Strepula sigmoidalis* Jones, 1890, by orginal designation of Warthin, 1934, p. 220, pl. 1, fig. 21.

Euglyphella asapha, n. sp.
Pl. 118, fig. 17, 18; Text-fig. 2

Description.—Carapace elongate, subtriangular in lateral view. Left valve larger than right with overlap strongest along dorsal and ventral margins. Hinge line and dorsal border slightly arcuate; ventral border concave, more so on the left valve. Posterior border narrowly rounded; strongly spinose. Anterior border broadly rounded; right valve occasionally has a spine where the anterior and dorsal borders meet. Left valve with small flange at posteroventral corner and another wider flange extending from the anterior corner to the anteroventral border. Right valve without posteroventral flange and with a narrower anterior flange.

Surface ornamented with ill-defined ridges, tubercles, and papillae. Loop-like ridge (*a* in Text-fig. 2) parallels the posteroventral border, becomes convex dorsally in the centroventral area, then curves down again, and continues dorsally parallel to the

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Explanation of Plate 115

Fig. *1,2*—*Hibbardia lacrimosa* (Swartz & Oriel). Right and left lateral views of two carapaces, 6th instar, hypotypes, NYSM 10891, 10892. ×30. (p. 1112)

3—*Phlyctiscapha subovata* Smith. Left lateral view of immature carapace, hypotype, NYSM 10893. ×25. (p. 1112)

4–6—*Strepulites divectus*, n. sp. *4,6*, Right lateral and dorsal views of carapace, holotype, NYSM 10894. *5*, Lateral view of left valve, paratype, NYSM 10895. ×25. (p. 1117)

7–9—*Octonaria bifurcata*, n. sp. *7,9*, Right lateral and dorsal views of carapace, holotype, NYSM 10898. *8*, Lateral view of left valve, paratype, NYSM 10899. ×30. (p. 1118)

10,11—*Bairdia summacuminata* Coryell & Malkin. Right lateral and ventral views of two carapaces, hypotypes, NYSM 10902, 10903. ×30. (p. 1119)

12—*Bythocypris subquadrata* Stewart. Right lateral view of carapace, hypotype, NYSM 10904. ×30. (p. 1119)

13,14—*Bythocypris lucasensis* Stewart. Right lateral views of two carapaces, hypotypes, NYSM 10905, 10906. ×30. (p. 1119)

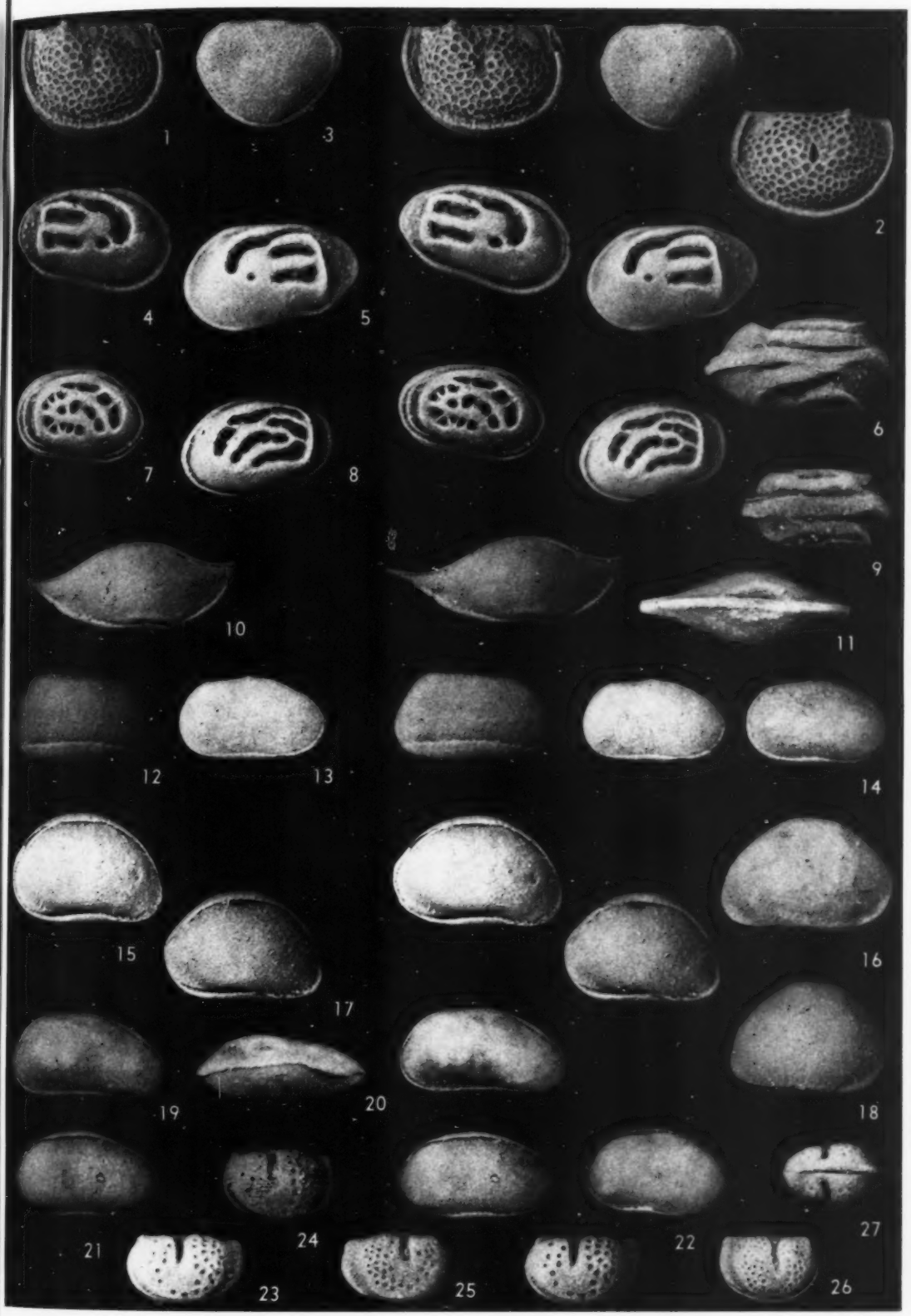
15,16—*Bythocypris transptyxis*, n. sp. Right and left lateral views of holotype, NYSM 10907. ×20. (p. 1120)

17,18—*Bythocypris transptyxis* var. *truncata*, n. var. Right and left lateral views of holotype, NYSM 10910. ×20. (p. 1120)

19,20—*Bythocypris phaseoella*, n. sp. *19*, Right lateral view of carapace, holotype, NYSM 10911. *20*, Dorsal view of carapace, paratype, NYSM 10912. ×25. (p. 1120)

21,22—*Bythocypris tubercula*, n. sp. *21*, Right lateral view of carapace, holotype, NYSM 10913. Right lateral view of another carapace, paratype, NYSM 10914. ×25. (p. 1120)

23–27—*Punctoprimitia subaequalis* Swartz & Oriel. *23,24*. Lateral views of two left valves, NYSM 10915, 10916. *25*. Lateral view of right valve, NYSM 10917. *26*, Right lateral view of immature carapace, NYSM 10918. *27*, Dorsal view of small carapace, NYSM 10919. Hypotypes. ×30. (p. 1112)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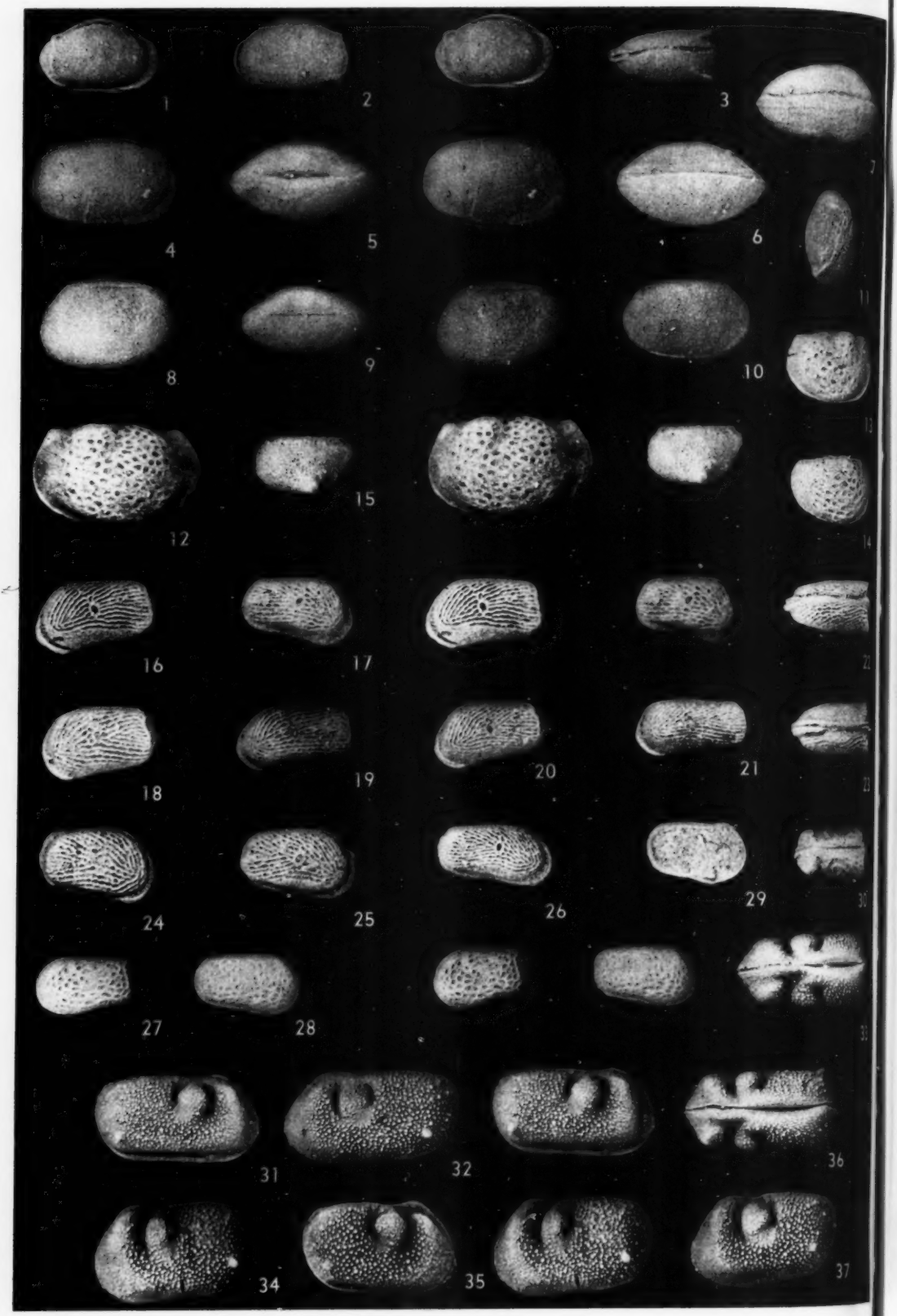
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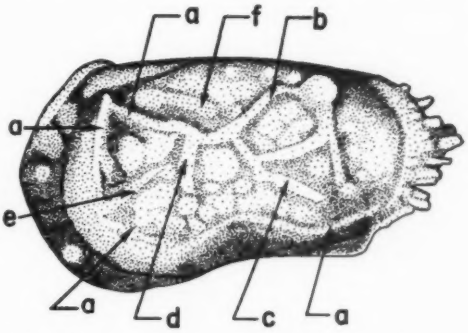
anterior border. Near the anterodorsal corner, the ridge swings down to the central area and bifurcates a little above the center. The upper segment (*b* in Text-fig. 2) extends posterodorsally and ends in a large, blunt spine or knob slightly below the dorsal margin. Lower segment (*c* in Text-fig. 2) slopes posteroventrally; in the posteroventral region, the ridge bends abruptly and continues dorsally to meet the knob at the posterodorsal end of the upper segment. Hence the ridges, posterior to the point of bifurcation, outline a triangular area in the posterocentral part of each valve. A subordinate curved ridge in the central area (*d* in Text-fig. 2) connects the dorsal and ventral limbs of the loop. The outer ridge is most prominent in the anterocentral area where it forms a short carina. On the left valve another ridge, beginning at the central area and inclined anteroventrally, divides the anterior part of loop (*e* in Text-fig. 2). In the centrodorsal area of the right valve are two small ridges which converge posteriorly; the left valve has only one short ridge (*f* in Text-fig. 2) in this area. These may be ornamented with papillae, tubercles or both. Row of tubercles parallels the anterior and another the posterior border on each valve.

Measurements.—Greatest length midway between dorsal and ventral borders; greatest



TEXT-FIG. 2—*Euglyphella asapha*, n. sp. Exterior view of left valve, ca. ×55. *a*, outer ridge; *b*, upper segment of outer ridge; *c*, lower segment; *d*, subordinate ridge, *e*, anterocentral ridge; *f*, central dorsal ridge. Drawing traced from enlarged photograph of specimen illustrated on Pl. 118, fig. 18.

EXPLANATION OF PLATE 116

(All magnification ×30 unless otherwise indicated)

FIG. *1–3*—*Healdia* cf. *H. arkonensis* Coryell & Malkin. *1*, Right lateral view of carapace, NYSM 10920. *2*, Lateral view of left valve, NYSM 10921. *3*, Dorsal view of capapace, NYSM 10922. (p. 1121)

4–7—*Coelonella scapha*, Stewart. *4*, Lateral view of carapace, NYSM 10923. *5,6*, Dorsal and ventral views of carapace, NYSM, 10924. *7*, Ventral view of another carapace, NYSM 10925. Hypotypes. (p. 1132)

8–11—*Paraparchites asymmetricus*, n. sp. *8,11*, Right lateral and posterior views of carapace, holotype, NYSM 10926. *9*, Dorsal view of another carapace, paratype, NYSM 10927. *10*, Left lateral view of carapace, paratype, NYSM 10928. (p. 1132)

12–14—*Paraschmidtella paralobata* (Swartz & Oriel). *12*, Lateral view of adult left valve, NYSM 10930. *13*, Lateral view of immature right valve, NYSM 10931. *14*, Lateral view of immature right valve, NYSM 10932. This specimen may prove to belong to another species. Hypotypes. (p. 1132)

15—*Monoceratina casei* Warthin. Left lateral view of carapace, hypotype, NYSM 10933. (p. 1113)

16–26—*Jenningsina catenulata* (Van Pelt). *16,17*, Left and right lateral views of two typical carapaces, NYSM 10934, 10935. *18–21*, Left lateral views of several carapaces showing variations in outline and ridge pattern, NYSM 10936–10939. *22,23*, Dorsal and ventral views of two typical carapaces, NYSM 10940, 10941. *24–26*, Right lateral views of three carapaces, NYSM 10936, 10942, 10943. Compare with fig. 16,18,19 and 20. Hypotypes. (p. 1122)

27–30—*Scalptina incuda*, n. gen., n. sp. *27*, Left lateral view of carapace, NYSM 10944. *28,30*, Right lateral and dorsal views of another carapace, holotype, NYSM 10945. *29*, Interior view of left valve, paratype, NYSM 10946. (p. 1123)

31–37—*Prosopeionum plexum*, n. gen., n. sp. *31–33*, Right lateral, left lateral and dorsal views of carapace, holotype, NYSM 10948. *34,36*, Left lateral and dorsal views of carapace, paratype, NYSM 10950. *35*, Right lateral view of another carapace, paratype, NYSM 10951. *37*, Left lateral view of immature carapace, NYSM 10952. Fig. 31,32 and 33 illustrate the elongate form; fig. 35, 36 and 37, the wide form. ×20. (p. 1123)

height located at approximately one-fourth the length from the anterior end; greatest convexity slightly ventrad to center. Dimensions of typical specimens are: length, 1.15 mm.; height, 0.63 mm.; width, 0.40 mm.

Remarks.—The new species is similar to *Euglyphella compressa* Coryell & Malkin, from the Widder beds of Ontario, Canada, but differs from it by having a less triganular outline, a narrower anterior flange, and a posteroventral flange on the left valve. In addition, the surface sculpture on *Euglyphella asapha*, n. sp., has very low relief, and the anterodorsal slope is gently rounded in contrast to a sharp, angular slope in *E. compressa*.

Occurrence.—Common at loc. 8, rare at loc. 7.

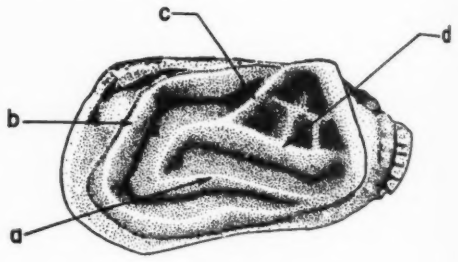
Specimens.—Holotype, a carapace, NYSM 10992; paratype, a left valve, NYSM 10993, both from loc. 7.

EUGLYPHELLA DELTELLA, n. sp.
Pl. 118, fig. 19–23; Text-fig. 3–5

Description.—Carapace subrhomboidal in lateral view; hexagonal elongate in dorsal view. Dorsal border slightly arcuate; ventral border concave in central part; anterior border broadly rounded, radius of curvature less in ventral half; posterior border narrowly rounded, acuminate centrally. Left valve larger than right; overlap inconspicuous.

In lateral view, the valves are ornamented by steep-sided ridges. An outer C-shaped ridge (*b* in Text fig. 3) nearly parallels the dorsal, anterior and ventral borders in the right valve. The corresponding ridge on the left valve is nearly straight in its anterodorsal part. An inner ridge (*a* in Text-fig. 3) is concentric to the outer one along its ventral and anterior segments and the anterior half of the dorsal segment. At the center of the valve the dorsal limb of the inner ridge divides. The upper part (*c* in Text-fig. 3) extends to the posterodorsal border where it bends abruptly and continues backward and downward to join with the ventral limbs of the inner and outer ridges in the posteroventral region; the lower part (*d* in Text-fig. 3) continues parallel to the ventral limb of the inner ridge for a short distance, then loops dorsally back upon itself. On the right valve only, the outer ridge terminates near the anterodorsal corner (Pl. 118, fig. 20), and a short horizontal ridge occurs in the central dorsal area. The sides of the ridges may be papillose, especially in the posterocentral area. Furrows between the ridges are deep.

The part of the valve outlined by the ridges is separated from the free border by a



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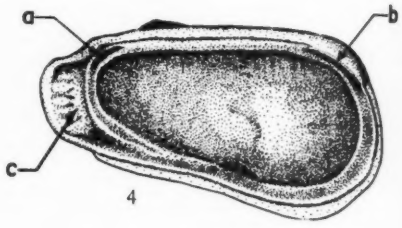

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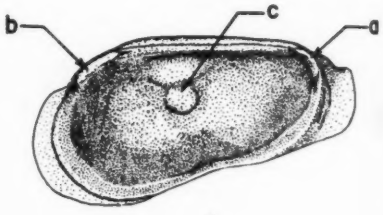

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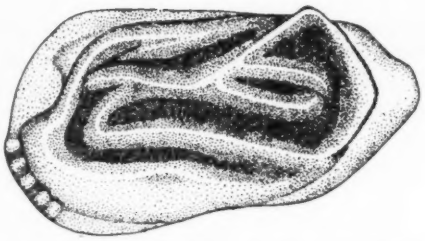
TEXT-FIG. 3–5—*Euglyphella deltella*, n. sp.
3—Exterior view of left valve, ca. ×55. *a*, inner ridge; *b*, outer ridge; *c*, upper segment of inner ridge; *d*, lower segment of inner ridge.
4—Interior view of left valve, ca. ×55. *a,b*, posterior and anterior dental sockets; *c*, radiating striae on posterior flange.
5—Interior view of right valve, ca. ×55. *a,b*, posterior and anterior teeth; *c*, adductor muscle scar boss.
Drawings traced from enlarged photographs of specimens shown on Pl. 118, fig. 21–23.



TEXT-FIG. 6—*Euglyphella projecta* Coryell & Malkin. Exterior view of left valve, ca. ×55. Compare with Text-fig. 3. Drawing made from pantographic enlargement of specimen illustrated by Coryell & Malkin, 1936, fig. 18, after examination of holotype.

low surface with scattered papillae, especially in the posterior region. Anterior and posterior marginal flanges lie outside the free edge; posterior flange broader but less high than the anterior one.

In interior view, the left valve is grooved to receive the smaller right valve. Hinge line approximately two-thirds as long as the valve. A bit ventrad and posterior to the dorsal groove and bar on the left valve is a small arcuate socket; another larger, vertically elongate socket occurs at the anterior end. These receive teeth from corresponding positions on the right valve; anterior tooth faintly crenulated (*a, b* in Text-fig. 4; *a, b* in Text-fig. 5). Adductor muscle scar located on a circular, convex boss, (*c* in Text-fig. 5) which lies a little anterior and dorsad of center. In some specimens the interior surface of the posterior flange has faint radiating striae (*c* in Text-fig. 4).

Measurements.—Greatest length approximately midway between dorsal and ventral borders; greatest height located at about one-fourth the length from the anterior end; greatest width, excluding posterior ridge, in the central area. Dimensions of a typical carapace are: length, 0.88 mm.; height, 0.47 mm.; width, 0.35 mm.

Remarks.—*Euglyphella deltella* closely resembles *E. projecta* Coryell & Malkin, but differs mostly in the posterior half as shown in Text-fig. 6. The new species lacks the small horizontal cross bars connecting the inner and outer loops in the anterocentral area. In general, the ridges are more sharply defined and rise abruptly from the lateral surface in *E. deltella*.

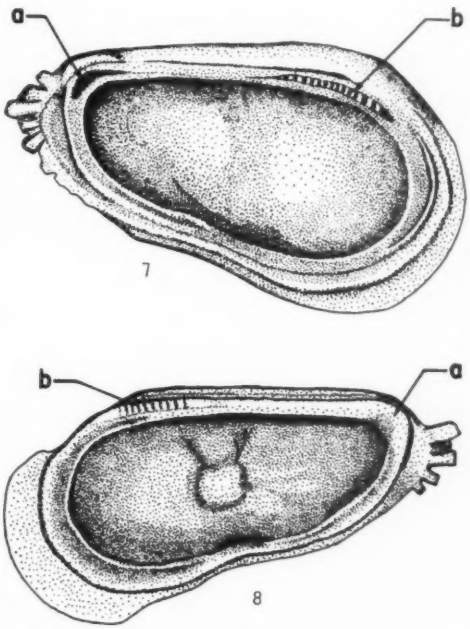
Occurrence.—Extremely abundant at loc. 7 and 8; common at loc. 9; rare at 2.

Specimens.—Holotype, a left valve, NYSM 10994; four paratypes, two carapaces, NYSM 10995, 10996, a right valve, NYSM 10997, and a left valve, NYSM 10998. All types from loc. 7.

EUGLYPHELLA NUMISMOIDES
Swartz & Oriel
Pl. 118, fig. 24–27; Text-fig. 7, 8

Euglyphella numismoides SWARTZ & ORIEL, 1948, p. 562–563, pl. 81, fig. 1–8.

Remarks.—The external features of *Euglyphella numismoides* were excellently described by the original authors. From a large collection, a few specimens were found that show beautifully the internal structures. The larger left valve has a narrow straight longitudinal groove along the hinge line, approximately two-thirds as long as the valve, which received the flange or upper contact edge of the right valve. Ventrad and posterior to the groove lies a crescent-shaped socket, convex posteriorly. A tooth at the corresponding position of the right valve fits into the socket. At the anterior end



TEXT-FIG. 7,8—*Euglyphella numismoides* Swartz & Oriel. Interior views of left and right valves, ca. × 55. *a,b*, posterior and anterior teeth and sockets. Note the crenulated anterior tooth. Drawings prepared from enlarged photographs of specimens illustrated on Pl. 118, fig. 24,25.

ventrad to and extending beyond the groove anteriorly is a narrow, arcuate area divided vertically by numerous minute teeth, similar to the taxodont tooth pattern in pelecypods. A similar but less pronounced set of teeth on the right valve meshes with those on the left. These features are illustrated in Text-fig. 7, 8.

A posteroventral flange is present on the left valve, similar to the one described on *Euglyphella asapha*. This flange varies in size from an almost imperceptible swelling to a distinct node-like projection.

Occurrence.—Extremely abundant at loc. 1 and 7; abundant at loc. 8; common at all other localities except 3 where it is rare.

Specimens.—Four hypotypes; a carapace, NYSM 10999, a left valve, NYSM 11000, and two right valves, NYSM 11001, 11002. All types from loc. 7.

Superfamily LEPERDITIACEA
Family LEPERDITELLIDAE Ulrich & Bassler, 1906
Genus COELONELLA Stewart

Type species: *Isochilina? scapha* Stewart, 1930, by original designation of Stewart, 1936, p. 742–743.

COELONELLA SCAPHA Stewart
Pl. 116, fig. 4–7

Isochilina? scapha STEWART, 1930, p. 57, pl. 1, fig. 11,12.
Coelonella scapha STEWART, 1936, p. 742–743, pl. 100, fig. 1,2. KESLING & WEISS, 1953, p. 67, pl. 5, fig. 13–16.

Remarks.—Along the free margin the larger right valve has an overlapping thin ribbon of shell material that in complete specimens extends almost to the summit of a small marginal ridge on the left valve. Also, on the left valve, very faint ridges commonly parallel the outer edge of the larger ridge for short distances around the carapace. Transverse sections show that the terminal and ventral margins of each valve extend past the center line of the carapace with the medial marginal areas of the left valve inside of and hidden from external view by the right valve.

Occurrence.—Common at loc. 7 and 8; rare at loc. 4, 6, and 9.

Specimens.—Hypotypes, one carapace, NYSM 10924, from loc. 7; two carapaces, NYSM 10923, 10925, from loc. 8.

Genus PARAPARCHITES Ulrich & Bassler

Type species: By original designation, *Paraparchites humerosus*, Ulrich & Bassler, 1906, p. 149–151, pl. 11, fig. 1–4.

PARAPARCHITES ASYMMETRICUS, n. sp.
Pl. 116, fig. 8–11

Description.—Carapace of medium size; ovate in lateral view, ellipitcal in end and dorsal views. Hinge line straight, sansabelloid. Dorsal border of left valve arcuate, extends above the hinge line; dorsal border of right valve straight; anterior and posterior borders of carapace evenly rounded; anterior end narrower than posterior end; ventral border moderately convex. Right valve overlaps left around the entire free border. Carapace strongly asymmetrical in lateral and terminal views. Lateral surfaces convex; smooth and without spines. Central dorsal area of left valve with distinct swelling. On some specimens the adductor muscle scar is expressed externally by a small spot located a little anterior of center.

Measurements.—Greatest length approximately midway between dorsal and ventral borders; greatest height a little posterior of center; greatest width slightly posteroventral of center. Dimensions of the holotype are: length, 0.72 mm.; height, 0.49 mm.; width, 0.36 mm.

Remarks.—*Paraparchites asymmetricus* lacks the small anterodorsal spine common in later Paleozoic species.

Occurrence.—Common at loc. 8; rare at loc. 7.

Specimens.—Holotype, a carapace, NYSM 10926, loc. 8; paratypes, another carapace, NYSM 10928, from loc. 7, and two additional carapaces, NYSM 10927, 10929, from loc. 8.

Genus PARASCHMIDTELLA Swartz

Type species: By original designation, *Paraschmidtella dorsopunctata* Swartz, 1936, p. 563, pl. 86, fig. 1a–c.

PARASCHMIDTELLA PARALOBATA (Swartz & Oriel)
Pl. 116, fig. 12–14

Punctaparchites (?) paralobatus SWARTZ & ORIEL, 1948, p. 550, pl. 79, fig. 1,2.

Remarks.—Swartz & Oriel (1948) questionably assigned this species to *Punctaparchites* Kay, 1934. In 1940 Kay (p. 244)

declared *Punctaparchites* a junior synonym of *Macronotella* Ulrich, 1894. The species under question lacks the smooth subcentral spot characteristically noted in species of *Macronotella*, and has a large extralobate area. It resembles the type species of *Paraschmidtella*, *P. dorsopunctata* Swartz, 1936, from the Lower Devonian Shriver chert of Pennsylvania, by having the central dorsal area project above the straight hinge line, and the anterior and posterior corners sharply truncated by the hinge line. However, the specimens from the Windom shale differ from *P. dorsopunctata* by possessing a larger extralobate area, an elliptical instead of a nearly circular outline in lateral view, and the lobate area ornamented with irregular reticulations rather than punctae.

The surface ornamentation is restricted to the inflated area of the valve and apparently consists of irregularly arranged pits in small specimens, but of distinct reticulations in larger individuals. The larger specimens differ further by being more elongate. The elongation is due to differential growth at the terminal, non-inflated parts of the valves. The central dorsal part of the inflated area is divided transversely by an obscure furrow which sets off two poorly defined lobes. In lateral view, the dorsal inflated part extends to or above the straight hinge line. *Paraschmidtella sulcella* (Swartz & Oriel) is probably an instar of *P. paralobata*.

Occurrence.—Rare at locs. 7 and 8.

Specimens.—Hypotypes, one mature left valve, NYSM 10930, and two immature valves, NYSM 10931, 10932; all from loc. 8.

Family incertae sedis

Genus *Kirkbyella* Coryell & Booth

Type species: By original designation *Kirkbyella typa* Coryell & Booth, 1933, p. 262.

KIRKBYELLA TORA, n. sp.
Pl. 119, fig. 17–22

Description.—Carapace small; subrectangular in dorsal and lateral views; subtrapezoidal in anterior view. Valves essentially equal. Dorsal border slightly arched in posterior half; anterior border unevenly rounded, radius of curvature less in ventral half; ventral border straight or gently convex dorsally in the central portion; posterior border broadly rounded; radius of curvature greater in dorsal half. Hinge line straight, approximately five-sixths as long as the valve. Hinge line and edge of free border invaginated.

A small lachrymoidal sulcus, inclined downward and backward, extends from a little below the hinge line to the center of the valve. A horizontally elongate swelling occurs in the ventral half of the carapace. It is outlined ventrally and terminally by a narrow arc-shaped ridge and dorsally by an irregular, smooth, longitudinal bar that ends posteriorly in a hollow bulb-like swelling.

A narrow smooth band parallels the dorsal and free borders. Surface of small specimens irregularly reticulose; larger specimens more coarsely reticulated and the reticulations are arranged in subhorizontal rows. In mature specimens, the posterior part of the ventral swelling tends to be smooth, and join with the marginal band.

Anterior corner rounded; cardinal angle approximately 130°; posterior corner rounded to acuminate, cardinal angle from 90° to 105°.

Measurements.—Greatest length through the horizontal bar; greatest height slightly posterior to the node; greatest width between the posterior knobs. Dimensions of the holotype are: length, 0.72 mm.; height, 0.40 mm.; width, 0.38 mm. and width across the ventral swelling, 0.35 mm.

Remarks.—*Kirkbyella tora*, n. sp., can be readily distinguished from *K. bellipuncta* (Van Pelt) from the Traverse group of Michigan by the prominent node at the posterior end of the longitudinal ridge. Whether or not the larger, more coarsely reticulated specimens are sex dimorphs of the smaller ones is not ascertainable; both forms have the central ventral swelling.

Occurrence.—Abundant at loc. 7 and 8; common at loc. 1 and 2; rare at loc. 6 and 9.

Specimens.—Holotype, a carapace, NYSM 11022; five paratypes including two mature right valves, NYSM 11019, 11020, a mature left valve, NYSM 11021, and immature right and left valves, NYSM 11024 and 11023, respectively. All types from loc. 7.

KIRKBYELLA UNICORNIS Coryell & Malkin
Pl. 119, fig. 26

Kirkbyella unicornis CORYELL & MALKIN, 1936, p. 5, fig. 13; WARTHIN, 1937, card 83.

Remarks.—Besides the specimens un-

questionably belonging to this species, three small, elongate specimens that lack the blunt posteroventral protuberance but have the finely reticulated surface typical of this species are tentatively assigned to *Kirkbyella unicornis*. These small forms are probably instars.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Hypotype, a carapace, NYSM 11028, loc. 8.

KIRKBYELLA VERTICALIS Coryell & Cuskley
Pl. 119, fig. 23–25

Kirkbyella verticalis CORYELL & CUSKLEY, 1934, p. 2, fig. 1.
Kirkbyella obliqua CORYELL & CUSKLEY, 1934, p. 2, fig. 2.
Kirkbyella verticalis WARTHIN, 1937, Card 85.

Supplementary description.—Valves subrhomboidal in lateral view. Dorsal border straight in anterior half, gently arched in posterior half, anterior border broadly rounded; ventral border straight; posterior border oblique or bluntly rounded posterodorsally; valves of equal size.

Sulcus small, extends from a little below the dorsal border to approximately one-third the distance to the ventral border. A prominent swelling occupies the ventral half of the carapace. Swelling narrows posteriorly and terminates in a blunt spine in the dorsal part of the posteroventral area. An indistinct marginal band parallels the entire free border, is constricted in the central ventral area, and is faintly reticulated or grooved.

Lateral surface with distinct, moderate-sized reticulations which tend to be aligned longitudinally. On some specimens the posterior area immediately dorsad to the ventral swelling has two or three ridges and grooves rather than reticulations.

Anterior cardinal angle approximately 120°; posterior cardinal angle approximately 100°.

Measurements.—Greatest length just below dorsal border; height nearly uniform between dorsal and ventral borders. Dimensions of a typical left valve are: length, 0.75 mm.; height, 0.38 mm.; width, 0.25 mm.

Remarks.—Warthin (1937) regarded *Kirkbyella obliqua* as a junior synonym of *K. verticalis*. The holotype of the latter is missing, but the Windom specimens compare favorably with the holotype of *K. obliqua*. If Warthin is correct, and *K. obliqua* and *K. verticalis* are conspecific, being either individual variants or sex dimorphs of the same species, then the classification of the Windom specimens is correct. However, should the two species be different, as originally interpreted by Coryell & Cuskley, then the specimens in this collection would be *K. obliqua*.

Occurrence.—Common at loc. 8; rare at loc. 1 and 7.

Specimens.—Hypotypes, 2 left valves, NYSM 11025, 11026, and a right valve, NYSM 11027, all from loc. 8.

Genus AMPHISSELLA, n. gen.

Type species: *Amphissella papillosa*, n. sp.

Description.—Carapace small, equivalved; subelliptical to subquadrate in lateral view; subelliptical in dorsal view. Lateral surface moderately convex, reticulated or reticulated and papillose, and with a small, smooth, round, central spot. Each valve with a narrow, smooth or papillated marginal ridge extending partially or completely around the free border. Hinge line straight; approximately two-thirds as long as the valve. Hingement simple; terminal teeth absent or poorly developed.

Remarks.—*Amphissella*, n. gen. closely resembles *Roundyella* Bradfield, 1935, but differs from it by having marginal structures. Sohn (1954), in his discussion of *Roundyella*, points out that Devonian species referred to *Roundyella* are probably not congeneric with the type. Besides the type species described below, *Amphissites tenuis* Warthin, 1934, from the Traverse group of Michigan is reassinged to the genus *Amphissella*. According to the illustrations, the specimens identified as *Amphissites simplicissimus* by Coryell & Malkin, 1936 (non *A. simplicissimus* Knight, 1928), from the Arkona shale of Ontario, should probably be included in this genus also.

AMPHISSELLA PAPILLOSA, n. sp.
Pl. 119, fig. 11,12

Description.—Carapace small, equivalved. Dorsal border straight or gently concave; anterior border broadly rounded, ventral border gently convex; posterior border symmetrically rounded. Hinge line straight.

slightly depressed, and approximately two-thirds as long as the valve. Dorsum smooth.

Lateral surfaces moderately convex, ornamented with polygonal reticulations and sparsely scattered papillae and with a smooth, circular spot at the center of each valve. A small node-like swelling occupies the anterodorsal corner, and in some specimens the lateral surface projects above the hinge line in this area. A small papillated marginal ridge parallels the free border. Channel very narrow and smooth. Immature specimens have a subrectangular outline in lateral view and a faint swelling at the posterior corner as well as the anterior corner.

Measurements.—Greatest length approximately midway between the dorsal and ventral borders; greatest height in anterior half; greatest width through the central spot. Dimensions of the holotype are: length, 0.61 mm.; height, 0.52 mm.; width, 0.28 mm.

Remarks.—*Amphissella papillosa*, n. sp., is easily recognizable by its small node-like swelling at the anterodorsal corner and papillated marginal ridge.

Occurrence.—Rare at loc. 7 and 8.

Specimens.—Holotype, a carapace, NYSM 11013, loc. 8; paratype a right valve, NYSM 11014, loc. 7.

Genus AMPHIZONA Kesling & Copeland

Type species: By original designation, *Amphizona asceta* Kesling & Copeland, 1954, p. 154.

AMPHIZONA ASCETA Kesling & Copeland
Pl. 119, fig. 6

Amphizona asceta KESLING & COPELAND, 1954, p. 154–162, pl. 1, fig. 1–31, pl. 2, fig. 1–4, 8–40.
Amphizona rowei COLEY, 1954, p. 462, pl. 53, fig. 4–5.

Remarks.—The specimens from the Windom shale, though numerous, consist mostly of instars and a few badly crushed or distorted adults. None of the specimens shows the coarse reticulations described and illustrated by the original authors for *Amphizona* cf. *A. asceta*.

Occurrence.—Common at loc. 7 and 8; rare at loc. 1 and 9.

Specimens.—Hypotype, a carapace, sixth instar, NYSM 11009, from loc. 8.

Genus CHIRONIPTRUM Kesling

Type species: By original designation, *Chironiptrum oiostathmicum* Kesling, 1952d p. 36.

CHIRONIPTRUM? ARCUATUM, n. sp.
Pl. 119, fig. 27–29

Description.—Carapace subrectangular in lateral view; sublanceolate in dorsal view. Dorsal border straight; ventral border gently curved; posterior and anterior borders unevenly rounded, more arcuate in the ventral half. Left valve slightly larger than right; overlap indistinct. Hinge line straight, depressed and nearly as long as the valve. Hingement not observed.

A narrow, poorly defined velate ridge parallels the entire free border, but is best developed in the central ventral area. The velate ridges nearly converge terminally and are confluent with the smooth dorsum. Channel smooth. Free edge of the contact border on left valve raised to form a faint median ridge.

Lateral surface inflated in the anterocentral area, less so in the posterocentral area. Entire lateral surface and upper surface of the velate ridges are finely reticulate; reticules small, polygonal, and without discernible geometric alignment. An elongate, inconspicuous pit about the size of two or three reticules is located slightly anterodorsal of center.

Anterior cardinal angle approximately 90°; posterior cardinal angle approximately 95°.

Measurements.—Greatest length at approximately one-fourth the distance from the dorsal border; greatest height through the central area; greatest width through the anterocentral swelling. Dimensions of the holotype: length, 0.92 mm.; height, 0.42 mm.; width, 0.38 mm. and the greatest width between the velate ridges, 0.19 mm.

Remarks.—*Chironiptrum? arcuatum*, n. sp., possesses features found in both *Kirkbya* and *Chironiptrum*. It resembles the former in general outline and ornamentation, but lacks a subcentral pit and has the terminal parts of the ridges greatly reduced; it is similar to *Chironiptrum* in that the velate ridges are confluent with the smooth dorsal margin and has a nearly central pit, but differs by having the lateral surface inflated anterocentrally. Apparently this species is intermediate between the two. Because all species unquestionably referred

to *Kirkbya* are Mississippian or younger and only one specimen of the new species was found, it is tentatively assigned to the Middle Devonian genus.

Occurrence.—Rare at loc. 8.

Specimen.—Holotype, a carapace, NYSM 11029, from loc. 8.

Genus DORACLATUM, n. gen.

Type species: *Doraclatum compandium*, n. sp.

Description.—Carapace subelliptical to subovate in lateral view; exclusive of node, sublanceolate in dorsal view, also sublanceolate in terminal view. Surface reticulate and papillose in small specimens, reticulate in larger ones. Each valve with a dorsal central node; subordinate nodes or swellings ventrad to the larger node may be present. A small bald spot or pit occurs near the center of each valve. Left valve slightly larger than the right. Free border with flattened median ridge. Hinge line straight.

Remarks.—Only the central dorsal node on each valve differentiates the new genus from *Roundyella*. Because of its nodes, *Doraclatum*, n. gen., is strikingly similar to *Aechminaria*, but the former lacks too many other features common to the various species of *Aechminaria* to be assigned to that genus or even the family Aechminidae.

DORACLATUM COMPANDIUM, n. sp.
Pl. 119, fig. 1–5

Description.—Carapace small, subelliptical in lateral view. Exclusive of nodes, sublanceolate in dorsal and end views. Left valve slightly larger than right; overlap most conspicuous along the ventral border. Dorsal border straight, ends evenly rounded, ventral margin straight to gently curved.

Each valve with prominent conical node located just below the dorsal margin and slightly anterior of center. Nodes project upward and forward in immature forms but are nearly perpendicular to the lateral surface in adults. Lateral surface gently inflated ventrad and slightly anterior to the node. Free border with compressed median ridge commonly rimmed by papillae. Ventrad and slightly posterior to the node is a small bald spot. This spot is unrecognizable in small individuals. Intermediate sized specimens have the spot surrounded by a rosette of from five to eight reticules, whereas in mature specimens the smooth spot is rimmed by numerous radially arranged reticules. During ontogeny the spot migrates from directly ventrad of the node to slightly posterior of it.

Lateral surface dominantly papillose in small specimens, but the larger ones have only a few scattered papillae near the mar-

EXPLANATION OF PLATE 117

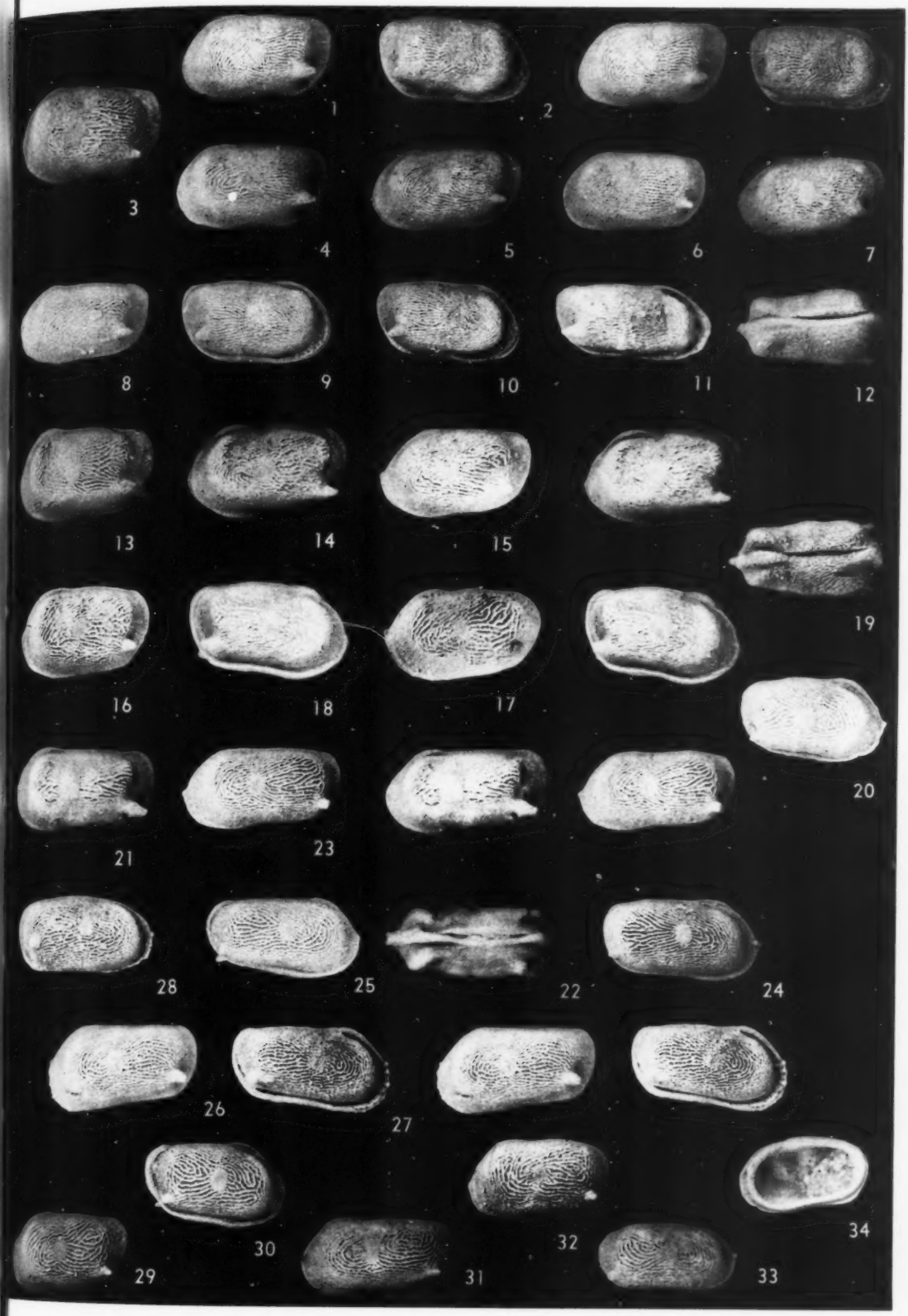
(All magnifications ×20 unless otherwise indicated)

FIG. *1–12*—*Quasillites subobliquus* Swartz & Oriel. *1,2*, Left and right lateral views of carapace, NYSM 10955. *3–8*, Left lateral views of several specimens illustrating the variations in outline, ornamentation, and development of the anterior ridge and posterodorsal swelling, NYSM 10956–10961. *9–11*, Right lateral views of three carapaces, NYSM 10957, 10962, 10961. *12*, Dorsal view of specimen shown in fig. 4. Hypotypes (p. 1125)

13–25—*Quasillites angulatus* Smith. *13–17*, Left lateral views of several specimens showing the variations in ornamentation, development of the anterior ridge and posterodorsal swelling, NYSM 10963–10967. *18*. Right lateral view of specimen shown in fig. 14, NYSM 10964. *19,20*, Dorsal and right lateral views of carapace similar to the specimen shown in fig. 17, NYSM 10968. *21,22*, Left lateral and dorsal views of carapace, elongate form; note the prominent anterior ridge and the posterodorsal node, also the relatively small area covered by lateral ridges, NYSM 10969. Compare with fig. 13. *23,24*, Left and right lateral views of carapace, elongate form, NYSM 10970. *25*, Right lateral view of another carapace, elongate form, NYSM 10971. Compare fig. 23,24 & 25 with fig. 17 & 20. Hypotypes (p. 1124)

26–28—*Quasillites* sp. *26,27*, Left and right lateral views of carapace, NYSM 10972. *28*, Lateral view of right valve, NYSM 10973. Note the denticles along the anteroventral margin and the straight dorsal border of the left valve. (p. 1126)

29–34—*Quasillites* spp., immature specimens. *29,30*, Left and right lateral views of carapace, probably an instar of *Q. angulatus*, NYSM 10974. *31*, Left lateral view of carapace, NYSM 10975. *32*, Lateral view of right valve, NYSM 10976. *33,34*, Exterior and interior views of right valves, NYSM 10977, 10978.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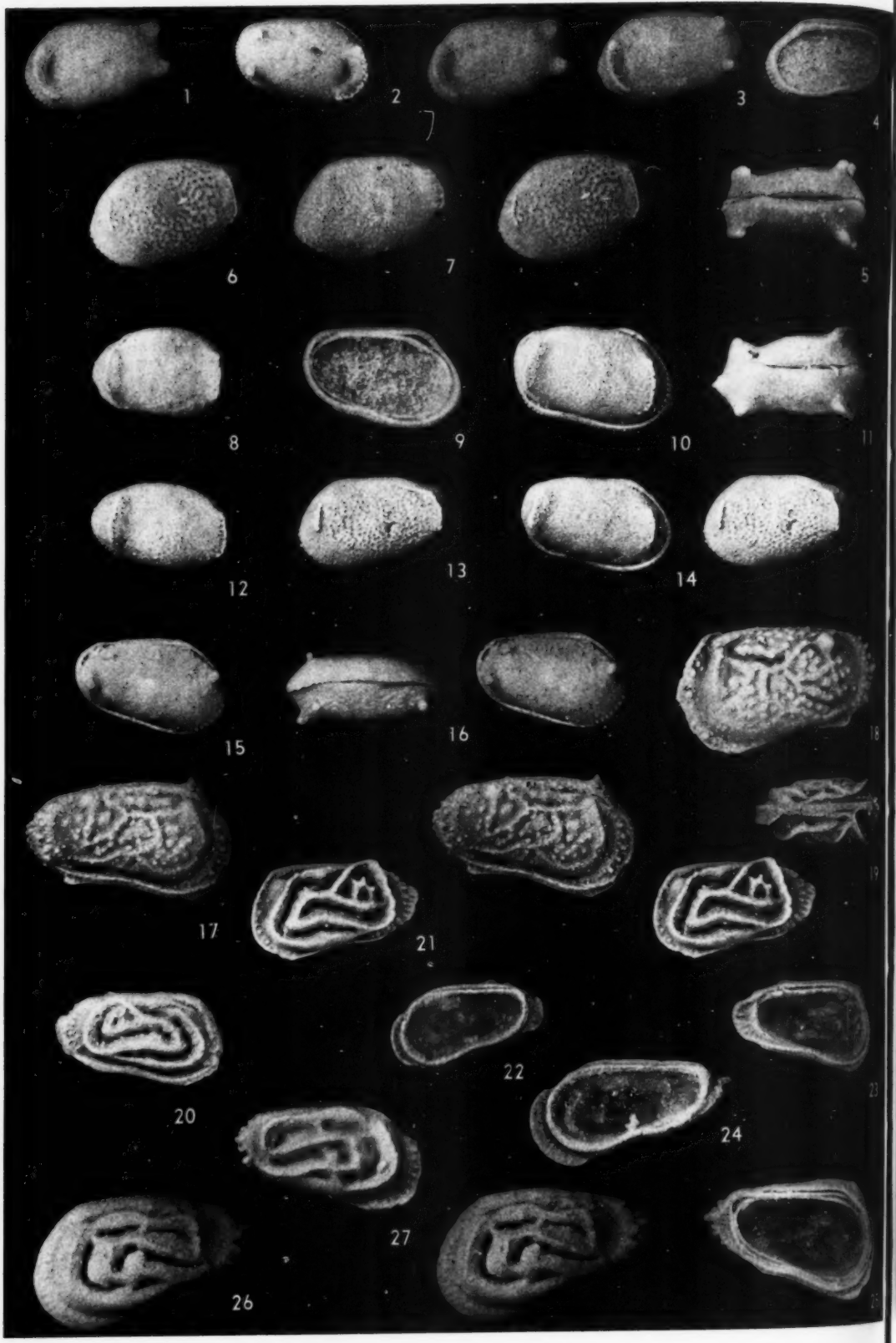
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gins; remainder of surface, including the node, almost entirely reticulose.

Anterior cardinal angle approximately 130°; posterior cardinal angle approximately 140°.

Measurements.—Greatest length approximately midway between the dorsal and ventral borders; height essentially uniform; greatest width through the anterocentral swelling. Dimensions of the holotype are: length, 0.58 mm.; height, 0.35 mm.; width 0.28 mm.

Remarks.—This species is distinghished by its dorsal nodes and the small bald spot surrounded by reticules. *Doraclatum compandium*, n. sp., closely resembles *Amphissites conatus* Coryell & Malkin, 1936, and may be congeneric or even conspecific with it. Unfortunately, the holotype of *A. conatus* is missing and the illustrations and descriptions of it are not sufficiently definitive to allow a direct comparison.

Occurrence.—Common at loc. 8; rare at loc. 7.

Specimens.—Holotype, a carapace, NYSM 11004, loc. 8; paratypes, 4 carapaces, NYSM 11005–11008, loc. 7.

Genus BIDEIRELLA, n. gen.

Type species: *Bideirella reticulata*, n. sp.

Description.—Carapace small, essentially equivalved; subrectangular to subelliptical in lateral view; elongate hexagonal in dorsal view. Dorsal border straight or gently arched; ventral border straight; ends rounded; lateral surface with two low vertical ridges on each valve near the ends. Surface, including the ridges, reticulated; each valve with a small central spot. A narrow smooth marginal band parallels the free and dorsal borders. Hinge line straight; hingement not observed.

Remarks.—*Bideirella*, n. gen., resembles *Moorea* Jones & Kirkby, but differs by having vertical ridges which are situated well inside the anterior and posterior borders rather than arcuate, marginal ridges. The new genus is also similar to *Hardinia;* however, the latter also has broad marginal ridges which are set off by sulci.

BIDEIRELLA RETICULATA, n. sp.
Pl. 119, fig. 7–10

Description.—Carapace small, equivalved; subrectangular in lateral and terminal views; extremely thin in dorsal view. Dorsal border straight or slightly curved; anterior and posterior ends evenly rounded; ventral border straight, parallel to dorsal border. Hinge line straight; approximately two-thirds as long as the valve.

Near the ends of each valve a vertical ridge extends the full height of the valve. Surface between the ridges slightly convex to strongly compressed; area outside the ridges gently convex. Entire surface retic-

EXPLANATION OF PLATE 118

(All magnifications ×30 unless otherwise indicated)

FIG. *1–5—Bufina bicornuta* (Ulrich). *1,2*, Left and right lateral views of a typical carapace, NYSM 10979. *3*, Left lateral view of another carapace, NYSM 10980. *4*, Interior view of right valve, NYSM 10981. *5*, Dorsal view of carapace, NYSM 10982. Hypotypes. ×25. (p. 1126)

6–11—Parabufina subovalis (Swartz & Oriel). *6*, Lateral view of left valve showing pitted surface and prominent adductor muscle spot, NYSM 10983. *7*, Lateral view of another left valve, NYSM 10984. *8*, Lateral view of right valve, NYSM 10985. *9*, Interior view of left valve showing distinct hinge teeth sockets and papillated free margin, NYSM 10986. *10*, Right lateral view of carapace, NYSM 10987. *11*, Dorsal view of another carapace, NYSM 10988. Hypotypes. (p. 1127)

12–14—Parabufina convexa Smith. *12*, Lateral view of right valve, NYSM 10989. *13*, Lateral view of left valve, NYSM 10990. *14*, Right lateral view of carapace, NYSM 10991. Hypotypes. (p. 1127)

15–16—?Lucasella spinulifera Stewart. Right lateral and dorsal views of carapace, NYSM 11003. Hypotype. (p. 1128)

17,18—Euglyphella asapha, n. sp. *17*, Right lateral view of carapace, holotype, NYSM 10992. *18*, Lateral view of left valve, paratype, NYSM 10993. (p. 1128)

19–23—Euglyphella deltella, n. sp. *19*, Dorsal view of carapace, paratype, NYSM 10996. *20*, Right lateral view of carapace, paratype, NYSM 10995. *21*, Lateral view of left valve, holotype, NYSM 10994. *22,23*, Interior views of a right and left valve, paratypes, NYSM 10997, 10998. (p. 1130)

24–27—Euglyphella numismoides Swartz & Oriel. *24,25*, Interior views of a right and left valve, NYSM 11000, 11001. *26*, Left lateral view of carapace, NYSM 10999. *27*, Lateral view of right valve, NYSM 11002. Hypotypes. (p. 1131)

ulated except for a thin marginal band that parallels all edges on both valves. A little anterior of center on each valve is a small bald spot, approximately the size of one reticule. Size and coarseness of reticulations variable.

Cardinal angles approximately equal, about 135°.

Measurements.—Greatest length midway between dorsal and ventral borders; height essentially uniform between the ridges; greatest width between the vertical ridges. Dimensions of the holotype are: length, 0.49 mm.; height, 0.30 mm.; width between the ridges, 0.19 mm.; width at the center of the carapace, 0.15 mm.

Remarks.—*Bideirella reticulata*, n. sp., may be recognized by its rectangular outline, the two non-marginal parallel ridges on each valve and the reticulated surface.

Occurrence.—Common at loc. 7.

Specimens.—Holotype, a carapace, NYSM 11012; paratypes, two additional carapaces, NYSM 11010, 11011, from loc. 7.

Genus ROUNDYELLA Bradfield

Type species: *Amphissites simplicissimus*, Knight, 1928, by original designation of Bradfield, 1935, p. 66.

ROUNDYELLA? CONCENTRICA, n. sp.
Pl. 119, fig. 13–16

Description.—Carapace small, elliptical in lateral view; elongate in dorsal view. Left valve slightly larger than right, overlap distinct. Dorsal border faintly arcuate, anterior and posterior borders evenly rounded; ventral border gently convex. Hinge line straight, slightly depressed, and approximately two-thirds as long as the valve. Hingement simple consisting of a simple tongue and groove without terminal teeth.

Lateral surface moderately convex, with a small central bald spot. Marginal areas smooth, remainder of surface ornamented with small reticulations arranged roughly concentrical to the central smooth spot. A little anterior of the center in the central dorsal area is a small swelling which is usually better expressed on the left valve. The swelling generally extends above the hinge line and on some specimens has a low, blunt spine on its anterior edge. Anterior and posterior corners rounded; cardinal angles about equal.

Measurements.—Greatest length through the bald spot; height essentially uniform between dorsal and ventral borders; greatest width between central dorsal swellings. Dimensions of a typical carapace are: length, 0.42 mm.; height, 0.28 mm.; width, 0.18 mm.

Remarks.—The new species strongly suggests *Roundyella* in outline, type of hingement, in having a small central smooth spot and by lacking marginal structures. However, its definite assignment to the genus is questionable because it has a small swelling anterior and dorsad to the central spot, lacks papillae, and is much smaller than previously described species, which are from Pennsylvanian and Permian rocks.

With its reticulated surface, *R.? concentrica* apparently is similar to the specimen referred to by Sohn (1954, p. 19) from the Hamilton of Ontario, but differs from it by not having a flat thick venter.

Definite generic assignment of *R.? concentrica* will probably depend upon future studies of other Devonian and, possibly, Mississippian assemblages.

Occurrence.—Common at loc. 7.

Specimens.—Holotype, a carapace, NYSM 11015; paratypes, two carapaces, NYSM 11016, 11018, and a left valve, NYSM 11017. All types from loc. 7.

Genus TUBULIBAIRDIA Swartz

Type species: By orginal designation, *Tubulibairdia tubulifera* Swartz, 1936, p. 581.

TUBULIBAIRDIA WINDOMENSIS Swartz & Oriel
Pl. 119, fig. 30–32

Tubulibairdia windomensis SWARTZ & ORIEL, 1948, p. 563. pl. 81, fig. 10–14.

Remarks.—Most of the specimens in this collection are more elongate than the holotype. Measurements of a typical specimen are: length, 1.08 mm.; height, 0.65 mm.; width, 0.68 mm.

Occurrence.—Common at loc. 8; rare at loc. 2 and 7.

Specimen.—Hypotype, a carapace, NYSM 11030, loc. 8.

Genus CRYPTOPHYLLUS Levinson

Type species: *Eridoconcha oboloides* Ulrich & Bassler, 1923, p. 296, pl. 14, fig.

6–8. by orginal designation of Levinson, 1941, p. 558.

CRYPTOPHYLLUS ARSINIUS, n. sp.
Pl. 119, fig. 37–40

Description.—Carapace small, umbonate; nearly circular in lateral view, elliptical in dorsal view, cardioid in end views. Hinge line straight short, depressed. A faint depression may occur at the summit of the umbonated dorsal border. Surface of larger specimens with from seven to nine subconcentric grooves, parallel to the free border; distance between grooves progressively greater ventrally. In ventral view, the grooves appear to converge posteriorly. Surfaces smooth.

Carapace equivalved or with slight overlap along the ventral border. Cardinal angles obtuse, nearly equal.

Measurements.—Greatest length midway between dorsal and ventral borders; greatest height through umbonal area; greatest width slightly dorsal or center. Dimensions of the holotype are: length, 0.46 mm.; height, 0.40 mm.; width, 0.29 mm.

Remarks.—*Cryptophyllus arsinius*, n. sp., resembles *C. concentricus* (Coryell & Williamson), 1936, from the Waldron shale (Silurian) of Indiana but differs from it by having a more nearly circular outline in lateral view. elliptical rather than circular grooves in the umbonal area and by apparently retaining more molts.

Occurrence.—Common at loc. 7; rare at loc. 1, 8, and 9.

Specimens.—Holotype, NYSM 11031, and three paratypes, NYSM 11032–11034, all carapaces from loc. 7.

Genus and species undetermined A
Pl. 119, fig. 33,34

Description.—Carapace medium sized, inequivalved. Right valve larger than left. Carapace reniform in lateral view, elliptical in dorsal view. Dorsal border short, gently arched; anterior border with long moderately steep anterodorsal slope, anteroventral portion very narrowly rounded, acuminate. Ventral border straight posterior border unevenly rounded, radius of curvature less in ventral half. In dorsal view, hinge line curved centrally, convex to the right. Overlap least along dorsal and posterior borders. Surfaces moderately convex, smooth.

Measurements.—Greatest length approximately one-fourth the distance from the ventral border; greatest height and width central. Dimensions of the two specimens are (mm.):

length	height	width
0.76	0.37	0.35
0.80	0.39	0.35

Remarks.—The specimens described above are similar to several genera in the Bairdiidae. They closely resemble *Macrocypris*, but the hingement is not known in species A, and no direct comparison is possible. In addition, *Macrocypris* is described as having the opposite overlap from *Bythocypris*. However, there is some doubt as to the validity of using overlap as a diagnostic generic characteristic. Several authors, the most recent being Kesling (1954), have demonstrated that the overlap can be either R/L or L/R in the same species. By simply reversing the orientation used here, the specimens resemble *Bythocypris* and *Pontocypris*, but again no definite assignment to those genera can be made because the internal features are not known and, in *Bythocypris*, the overlap along the dorsal border is generally greater than shown in these specimens. Not to be overlooked is the possibility that they are young forms of a species of *Bairdia*. No internal features were observed that would confirm or deny the orientation employed here.

Occurrence.—Rare at loc. 8.

Specimens.—Figured carapace, NYSM 11035.

Genus and species undetermined B
Pl. 119, fig. 35,36

Description.—Carapace medium sized, inequivalved. Reniform in lateral view, elliptical in dorsal view. Dorsal border straight; anterior border unevenly rounded, anterodorsal border moderately steep, anteroventral border narrowly rounded; ventral border straight; posterior border rounded; radius of curvature less in ventral half. Right valve overlaps left along dorsal border; left valve overlaps right along ventral border; extremities without overlap. Carapace inequally convex; greatest convexity of right valve in dorsal half; greatest convexity of left valve in ventral half. Carapace smooth.

Measurements.—Greatest length approximately one-fourth the distance from the ventral border; greatest width and height through the central area. Dimensions of the two carapaces are (mm.):

length	height	width
0.76	0.36	0.31
0.69	0.32	0.28

Remarks.—The strong asymmetry of the carapace in end view coupled with the unusual overlap relationships in species B is suggestive of *Paraparchites*. However, the specimens described above are more elongate and lack the definite swing of the carapace common in *Paraparchites*. The hingement and internal features were not observed.

Occurrence.—Rare at loc. 8.

Specimen.—Figured carapace, NYSM 11036.

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MANUSCRIPT RECEIVED JANUARY 20, 1956.

EXPLANATION OF PLATE 119

(All magnifications ×30 unless otherwise indicated)

FIG. *1–5—Doraclatum compandium*, n. gen., n. sp. *1*, Left lateral view of carapace, holotype, NYSM 11004. *2,3*, Lateral views of two immature specimens, NYSM 11005, 11006. *4,5*, Dorsal and ventral views of small carapaces, NYSM 11007, 11008. Paratypes. (p. 1136)

6—Amphizona asceta Kesling & Copeland. Left lateral view of immature carapace, 6th instar, NYSM 11009. Hypotype. ×25. (p. 1135)

7–10—Bideirella reticulata, n. gen., n. sp. *7*, Lateral view of carapace, paratype, NYSM 11010. *8,9*, Dorsal and lateral view of another carapace, paratype, NYSM 11011. *10*, Lateral view of carapace, holotype, NYSM 11012. (p. 1137)

11,12—Amphissella papillosa, n. gen., n. sp. *11*, Left lateral view of carapace, holotype, NYSM 11013. *12*, Lateral view of right valve, paratype, NYSM 11014. (p. 1134)

13–16—Roundyella? concentrica, n. sp. *13*, Right lateral view of carapace, holotype, NYSM 11015. *14,15*, Left lateral and dorsal views of carapace, paratype, NYSM 11016. *16*, Lateral view of left valve, paratype, NYSM 11017. (p. 1138)

17–22—Kirkbyella tora, n. sp. *17,18*, Lateral views of two right valves, paratypes, NYSM 11019, 11020. *19*, Lateral view of left valve, paratype, NYSM 11021. *20*, Dorsal view of carapace, holotype, NYSM 11022. *21,22*, Lateral views of immature left and right valves, paratypes, NYSM 11023, 11024. (p. 1133)

23–25—Kirkbyella verticalis Coryell & Cuskley. *23,24*, Lateral views of two left valves, NYSM 11025, 11026. *25*, Lateral view of right valve, NYSM 11027. Hypotypes. (p. 1134)

26—Kirkbyella unicornis Coryell & Malkin. Left lateral view of carapace, hypotype, NYSM 11028. (p. 1133)

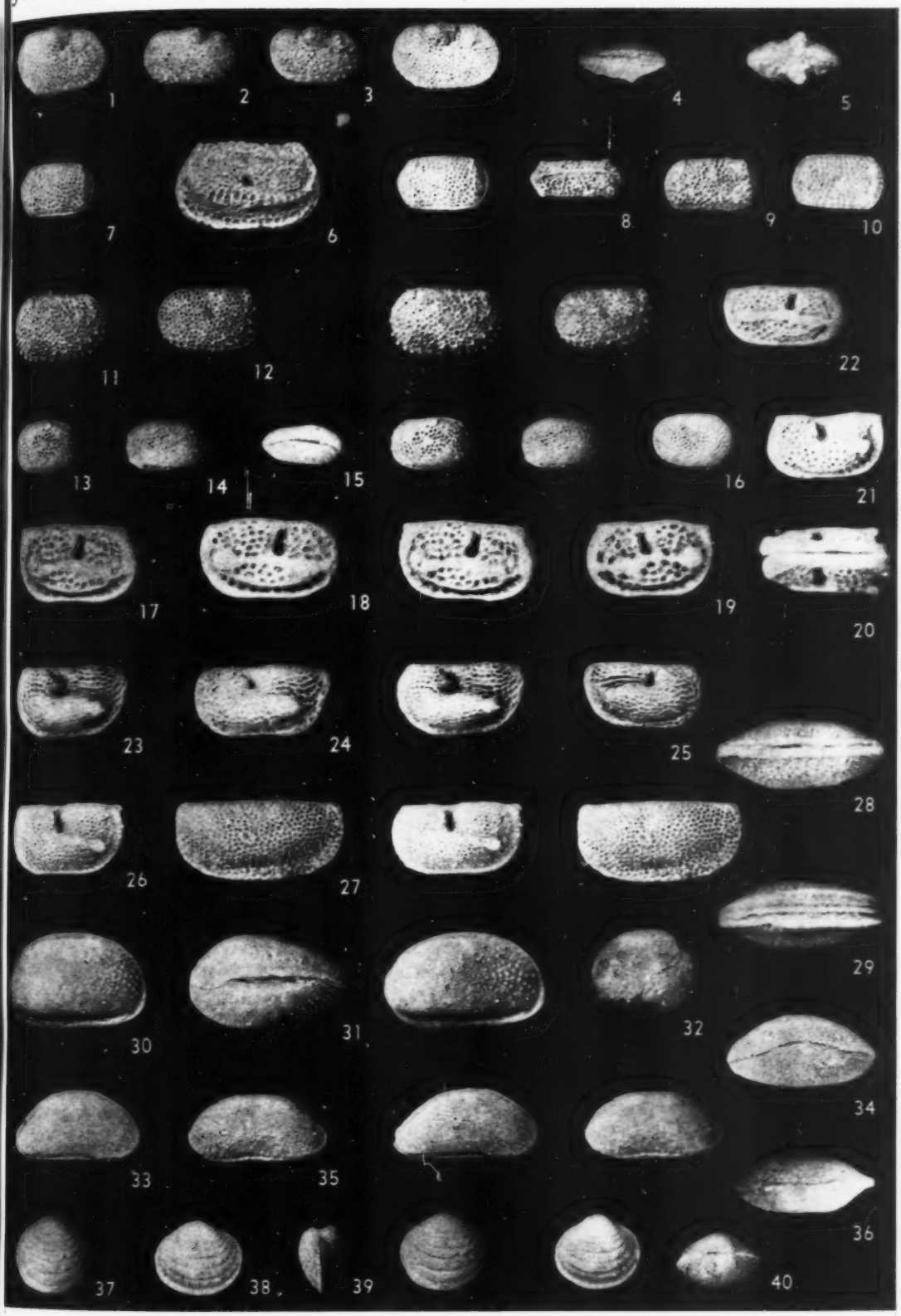
27–29—Chironiptrum? arcuatum, n. sp. Left lateral, dorsal and ventral views of carapace, holotype, NYSM 11029. (p. 1135)

30–32—Tubulibairdia windomensis Swartz & Oriel. Right lateral dorsal and posterior views of a typical carapace, hypotype, NYSM 11030. The pores at the anterior end are filled with secondary pyrite which stands out in relief. ×25. (p. 1139)

33,34—Genus and species undet. A. Lateral and dorsal views of carapace, NYSM 11035. (p. 1139)

35,36—Genus and species undet. B. Lateral and dorsal views of carapace, NYSM 11036. (p. 1139)

37–40—Cryptophyllus arsinius, n. sp. *37*, Lateral view of carapace, holotype, NYSM 11031. *38*, Lateral view of another carapace, paratype, NYSM 11032. *39*, Terminal view of carapace, paratype, NYSM 11034. *40*, Dorsal view of carapace, paratype, NYSM 11033. (p. 1139)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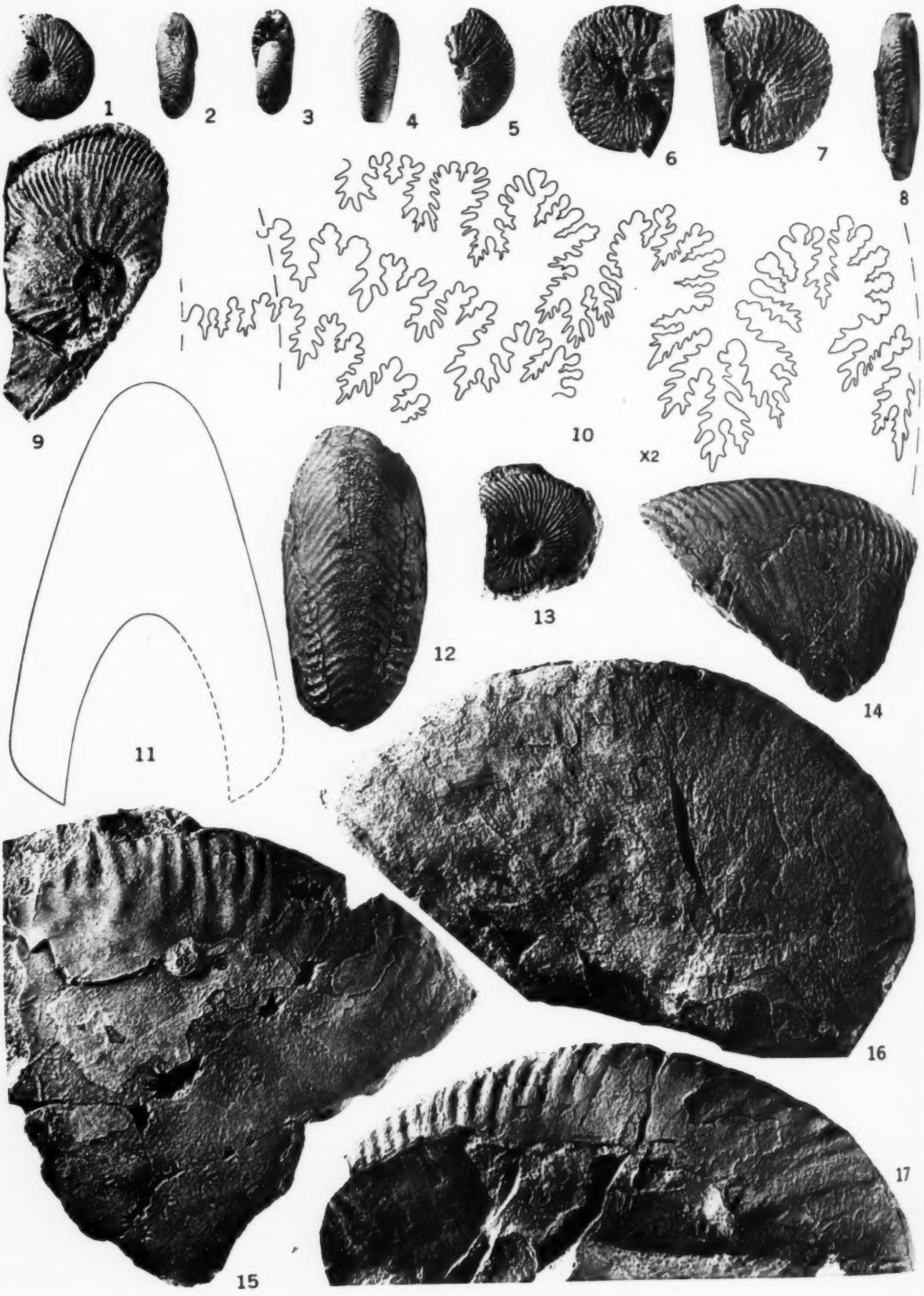
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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1143–1146, PL. 120, SEPTEMBER 1956

STRATIGRAPHIC AND GEOGRAPHIC RANGE OF THE EARLY CRETACEOUS AMMONITE *HOMOLSOMITES*[1]

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ABSTRACT—The Early Cretaceous (Valanginian) ammonite *Homolsomites* Crickmay, based on imperfect specimens of *H. poecilochotomus* Crickmay (=*Holcodiscus? stantoni* McLellan) from southwestern British Columbia, is redefined and the name applied to species from California, Oregon, Washington, and Greenland that have been described under other generic names. The genus is closely related to *Tollia* Pavlow from the late Berriasian of the Boreal region and is referred to the family Craspeditidae. *Homolsomites* is commonly associated with the pelecypod *Aucella crassicollis* Keyserling and with the ammonites *Polyptychites*, *Neocraspedites*, *Lyticoceras*, and *Sarasinella*.

DISCUSSION

THE ammonite *Homolsomites* was described and assigned to the family Virgatitidae by Crickmay in 1930 (p. 63) in his studies of the fossils from the Harrison Lake area of southwestern British Columbia. His definition was as follows:

> The genus *Homolsomites* includes platycones with narrow umbilicus and narrow though rounded venter. Costae, delicate, branching according to various plans, but mostly virgatome, and crossing centre unbroken and with a strong forward bend. In maturity all but the ventral ornament become obsolete. Septum strongly inclined. Stems of lobes narrower than is usual with this family.

One species, *H. poecilochotomus*, was described by Crickmay (1930, p. 63, 64, pl. 21, fig. 1–4). His description is brief, but adequate, and the illustrations are fairly good considering the preservation of the type specimens. The holotype probably represents part of the body chamber of a mature specimen on which the ribbing has nearly disappeared from the lower half of the flanks. This specimen is much worn, however, and the published illustration gives a misleading impression of smoothness on the upper part of the flanks. A plaster replica of the holotype shows that its right side has strong forwardly inclined ribbing on the upper part of the flanks and on the venter and that there are several forwardly inclined constrictions. The presence of constrictions was not mentioned by Crickmay although the paratype shown on his pl. 21, fig. 1 appears to have several.

The name *Homolsomites* has not been used since defined by Crickmay, probably because of the fragmentary condition of the type specimens, but the genus was adequately defined and its name may be applied

[1] Publication authorized by the Director, U. S. Geological Survey.

EXPLANATION OF PLATE 120

All figures natural size except suture-line.

FIG. *1–12,14,15—Homolsomites stantoni* (McLellan). *1–3*, Lateral, ventral, and apertural view of immature specimen from Spieden Bluff on northwest side of Spieden Island, Washington. *4,5*, Ventral and lateral views of immature specimen from Spieden Bluff. *6–8*, Lateral and ventral views of immature specimen from Skyline Trail near Glacier. *9*, Medium-size specimen from Spieden Bluff. *10,11,15*, Suture-line (×2), cross-section, and lateral view of posterior end of body chamber of a large specimen from Spieden Bluff. *12,14*, Ventral and lateral views of posterior end of penultimate whorl of same specimen shown in fig. 15.

13,16,17—Homolsomites poecilochotomus Crickmay. *13*, Lateral view of small paratype (Nat. Mus. Canada Bull. 63, pl. 21, fig. 4) for comparison with fig. 1–8 of *H. stantoni* (McLellan). *16,17*, Left and right sides of plaster replica of holotype to show strong ribbing on venter and for comparison with fig. 15 of *H. stantoni* (McLellan). Type specimens from Harrison Lake area, southwestern British Columbia.

usefully to certain species from the West Coast of North America and from East Greenland.

The following species are herein included in *Homolsomites:*

Olcostephanus (*Simbirskites*) *mutabilis* Stanton (1895, p. 77, 78, pl. 15, fig. 1–5).
Holcodiscus? stantoni McLellan (1927, p. 115, pl. 12, fig. 3–5). This paper, Pl. 120, fig. 1–12,14,15.
Homolsomites poecilochotomus Crickmay (1930, p. 63,64, pl. 21, fig. 1–4). This paper, Pl. 120, fig. 13,16,17.
Dichotomites tehamaensis Anderson (1938, p. 158, pl. 28, fig. 2; pl. 30, fig. 6)
Dichotomites gregerseni Anderson (1938, p. 158, pl. 28, fig. 3,4)
Dichotomites burgeri Anderson (1938, p. 159, pl. 28, fig. 5)
Dichotomites gregerseni var. *paucicostatus* Donovan (1953, p. 110–112, pl. 23, fig. 1a,b)

On the basis of the features common to these species, the genus *Homolsomites* includes shells that are compressed, narrowly rounded ventrally, and narrowly umbilicated. The primary ribs are sharp on the inner whorls, but not appreciably stronger than the secondary ribs. During growth the primary ribs become much more prominent than the secondary ribs and on the penultimate whorl have a pinched appearance. On the body chamber they tend to weaken or become indistinct. The secondary ribs are closely spaced, much more numerous than the primary ribs, arch forward strongly on the venter and are not reduced in strength along the midline. Rib branching occurs by two's and three's between the middle and the lower fourth of the flanks. Some branches divide again on the upper half of the flanks. Forwardly inclined constrictions are conspicuous on the penultimate and body whorls. Tubercles are not present.

The last suture-line adjoining the body chamber and a part of the two preceding suture lines of a specimen from Spieden Island, Washington, are illustrated herein. The suture-line has fairly long saddles and lobes. The first lateral lobe is slightly longer than the external lobe and much longer than the second lateral lobe. There are four fairly narrow auxiliary lobes on the flank that ascend toward the umbilicus and three very small lobes on the umbilical wall that descend toward the umbilicus. The second lateral saddle is nearly as broad as the first lateral saddle. The auxiliary saddles are much smaller than the lateral saddles but are a little broader than the auxiliary lobes.

The suture-line of *Homolsomites mutabilis* (Stanton) (1896, pl. 15, fig. 2) as illustrated does not show the first lateral lobe, or the external lobe, but these are visible on the same side of the specimen from which Stanton made his drawing. The suture-line is comparable to the one just described in proportions. It has a fairly low external lobe, a narrow and slightly longer first lateral lobe, and a very short second lateral lobe. The first and second lateral saddles are nearly as broad as the external saddle.

The species of *Homolsomites* from the Pacific Coast of the United States have been referred to such genera as *Olcostephanus, Simbirskites, Dichotomites, Holcodiscus?,* and *Subcraspedites.* In comparison with *Homolsomites, Holcodiscus* has a rounder cross section and less tight coiling; *Olcostephanus* and *Simbirskites* are readily distinguished by the presence of tubercles; *Dichotomites* has rib branching at the umbilical margin, less prominent primary ribs, and a rounder cross section; *Subcraspedites* differs by its lack of pronounced constrictions, by developing umbilical bulges in the adult, by its ribbing weakening on the venter in the adult, by being less involute, and by having a shorter first lateral lobe. *Homolsomites mutablis* (Stanton), was once referred by Spath (1923, p. 306) to *Subcraspedites,* but he later (1947, p. 27) expressed doubt about this identification because of the presence of constrictions and of certain peculiarities of the suture line.

Homolsomites resembles *Tollia* (Pavlow, 1914, p. 38–42, pl. 12,13; Spath, 1936, p. 85; 1947, p. 25, 26; 1952, pl. 4, fig. 8) from the upper Berriasian of northern Siberia, Novaya Zemlya, and Greenland much more than it resembles the early Berriasian *Subcraspedites.* It agrees closely in shape, involution, ribbing, constrictions, and suture-line. *H. mutablis* (Stanton, 1896, p. 77, pl. 15, fig. 1–5) is similar to *Tollia tolmatschowi* Pavlow (1914, p. 40, pl. 13, fig. 1e,f) but has much deeper constrictions. *H. stantoni* (McLellan) (1927, p. 115, pl. 12, fig. 3–5) is similar in fineness of ribbing and in cross-section to *Olcostephanus sosnovskii* Sokolow (1913, p. 70, pl. 2, fig. 2a–c, text-fig. 4,5 on p. 70), which Spath (1936, p. 85) suggests belongs to *Tollia* rather than *Subcraspedites* on the basis of its suture-line.

Tollia differs from *Homolsomites* by hav-

ing shorter, weaker primary ribs; by its secondary ribs being less commonly joined with the primary ribs; by attaining a much larger size; by becoming smooth in the adult except for constrictions; and by having stouter first and second lateral lobes. Spath (1947, p. 26) says that the suture-line of *Tollia* has a high external lobe, but his drawing (1947, p. 25, text-fig. 7b) of *Tollia latelobata* Pavlow (1914, pl. 13, fig. 2) does not show all of the external lobe that is visible on the original plate. Allowing for this, the suture-line of *Tollia* appears to differ from that of *Homolsomites* mainly by the greater stoutness of its lobes. Maintaining *Homolsomites* and *Tollia* as separate genera is justified by the distinctions noted above and by their occurrences at different stratigraphic levels.

The resemblance of *Homolsomites* to *Tollia* justifies placing both in the same family. *Tollia* has been placed by Spath (1952, p. 10) in the subfamily Toliinae of the family Craspeditidae, but he notes (1947, p. 26) that *Tollia* is transitional to the Polyptychitidae. Such a transitional position is indicated by whorl shape, rib branching, and suture-line. An assignment to the Polyptychitidae would be justified if Donovan (1953, p. 111) is correct concerning the assignment of *Polyptychites anabarensis* Pavlow (1914, p. 27, pl. 4, fig. 3a,b) to the group of species here included under *Homolsomites*.

Homolsomites throughout its known area of distribution in North America is associated with large, coarsely ribbed aucellas that are commonly referred to *Aucella crassicollis* Keyserling and are considered characteristic of the Valanginian stage. At many places *Homolsomites* is associated with ammonites of middle to late Valanginian age including *Polyptychites*, *Neocraspedites*, *Lyticoceras*, and *Sarasinella*.

The four species from California described by Stanton and Anderson were obtained about 5 miles north of Paskenta at nearly the same stratigraphic position. At the same locality as the type specimen of *Homolsomites mutabilis* (Stanton) was found *Sarasinella angulata* (Stanton) (1895, p. 80, pl. 18, fig. 3,4), whose generic position is indicated by its trituberculate inner whorls. From the locality at which Anderson obtained his three species of "*Dichotomites*" were also found *Polyptychites trichotomous* (Stanton) (1896, p. 78, pl. 16, fig. 1) and *Neocraspedites* (Stanton, 1896, p. 77, listed as *Desmoceras?* sp.).

In southwestern Oregon specimens of *Homolsomites* have been found at the forks of Elk River, Curry County, associated with *Lyticoceras* and *Sarasinella*. In northwestern Washington the type specimens of *H. stantoni* (McLellan) (1927, p. 115, pl. 12, fig. 3–5) were obtained from Spieden Island in the San Juan Island group and the other specimens studied by McLellan were obtained from the south bank of the Nooksook River about 2 miles east of the village of Glacier in sec. 5, T. 39 N., R. 7 E., which is in the northern Cascade Mountains north of Mt. Baker. At a nearby locality Peter Misch of the University of Washington recently found a small specimen of *Homolsomites* on the lower part of the Skyline Trail southeast of Glacier.

This specimen, submitted to the writer for examination, proved to be of unusual value as it furnished the clue to the generic status of several species occurring in beds of Valanginian age along the Pacific Coast. It was found to be very similar in size, shape, and ribbing with both the small paratype of *H. poecilochotomus* Crickmay (1930, pl. 21, fig. 4) and with the types of *Holcodiscus? stantoni* McLellan. To confirm this identification plaster replicas of *H. poecilochotomus* Crickmay were obtained from the Geological Survey of Canada and specimens of *Holcodiscus? stantoni* McLellan from the type locality on Spieden Island were borrowed from the Geology Department of the University of Washington. The specimens from British Columbia and Washington are herein illustrated for comparison to show that *H. poecilochotomus* is a synonym of *H. stantoni*. Such is not surprising considering that the types of *H. poecilochotomus* were obtained only about 40 miles north of Glacier, Washington, along the continuation of the same mountains. The actual types of *Holcodiscus? stantoni* have not been found, but the specimens available from Spieden Island belong to the same species and represent several stages of growth.

Some specimens of *Homolsomites* from Trail Island in East Greenland were assigned by Donovan (1953, p. 33, 34, 110) to *Dichotomites*, although he showed clearly that they

differed from typical *Dichotomites* by their prominent primary ribs and a lack of rib branching at the umbilical margin. It is doubtful if Donovan was aware of Crickmay's genus, or could recognize it because of lack of comparative material. His specimens of *Homolsomites* were associated with *Polyptychites*, *Euryptychites*, *Neocraspedites*, and *Aucella crassicollis* Keyserling.

Donovan (1953, p. 111) considered that the group of species, herein referred to *Homolsomites*, included *Polyptychites anabarensis* Pavlow from northern Siberia (Pavlow, 1914, p. 27, pl. 4, fig. 3a,b) and Novaya Zemlya (Frebold, 1930, p. 84) and possibly *Olcostephanus fragilis* Pavlow (not Trautsch) (Pavlow, 1892, p. 475, pl. 6, fig. 3,4) from Speeton, England. Of these, *Polyptychites anabarensis* appears to differ from *Homolsomites* by lacking constrictions and by having fairly regular rib bifurcation near the middle of the flanks. The small specimens that Pavlow referred to *Olcostephanus fragilis* probably do not belong to *Homolsomites* because they have weak ribs on the lower parts of their flanks in contrast to the sharp ribs on *Homolsomites* at comparable sizes.

The ammonite genera and the coarsely-ribbed, robust aucellas associated with *Homolsomites* in North America show that it is of middle to late Valanginian age. In Europe *Euryptychites* ranges through the early and middle Valanginian. *Polyptychites* and *Sarasinella* through the middle and late Valanginian, *Lyticoceras* from the late Valanginian into the middle Hauterivian, and *Neocraspedites* from the middle Valanginian into the early Hauterivian. Probably most of the occurrences of *Homolsomites* are of middle Valanginian age, but its association with *Lyticoceras* in southwestern Oregon suggests that it ranges into the late Valanginian.

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MANUSCRIPT RECEIVED FEBRUARY 4, 1956.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1147–1153, 2 TEXT-FIG., SEPTEMBER 1956

"*TRACHYCERAS* ZONE" IN THE UPPER TRIASSIC OF THE WESTERN UNITED STATES[1]

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ABSTRACT—The name "*Trachyceras* subzone" proposed by J. P. Smith as a subdivision of the late Karnian *Tropites subbullatus* zone in northern California has been perpetuated in geological literature although it is ambiguous and based on a misconception. The ammonites from this subzone assigned by Smith to *Trachyceras* (*Protrachyceras*) are morphologically distinct from the characteristic members of this group. Furthermore, the associated fauna is comparable to the Alpine late Karnian *Tropites subbullatus* zone and contains no elements indicative of the early Karnian *Trachyceras aon* or *T. aonoides* zones to which the genus *Trachyceras* s.s. is restricted. Thus, the seemingly anomalous joint occurrence of *Trachyceras* s.l. and *Tropites* cannot be explained by an early appearance of *Tropites* in western North America, as suggested by Smith, but is due instead to the misidentification of *Trachyceras* s.l. in a fauna characteristic of the late Karnian. As the *Trachyceras aon* and *T. aonoides* zones, or the less precise *Trachyceras* zone in its commonly accepted meaning, can be recognized in Nevada in their proper position in the standard sequence of Middle and Upper Triassic faunal zones, Smith's "*Trachyceras* subzone" is an undesirable homonym. The name *Tropites dilleri* subzone is proposed to replace Smith's name and the forms from this subzone assigned to *Trachyceras* s.l. by Smith are transferred to a new genus, *Spirogmoceras* (type species: *Protrachyceras shastense* Smith).

THE "*Trachyceras* SUBZONE" IN CALIFORNIA

THE "*Trachyceras* subzone," proposed by J. P. Smith as a subdivision of the *Tropites subbullatus* zone in Shasta County, California, is the only established usage of the generic name *Trachyceras* as the index for a time-stratigraphic unit of rocks in North America. The strata of this subzone are included in a lithologic unit considered by Smith equivalent to the Hosselkus limestone of the Taylorsville area in Plumas County, California. This correlation is subject to interpretation and consequently the name Hosselkus limestone is used here as applied by Smith in Shasta County, recognizing that it may be incorrect.

To judge the suitability of the name "*Trachyceras* subzone" as a local subdivision of the *Tropites subbullatus* zone it is enlightening to trace the evolution of this name in Smith's writings. The genus *Trachyceras* was first reported from the Hosselkus limestone of Shasta County by Smith in 1894 (p. 606). Several forms were listed as having affinity with, or being comparable to, species described from the Alps that belong either to the subgenus *Trachyceras* s.s., *Protrachyceras*, or *Anolcites*. Among other species listed in the same fauna from California were several species of *Tropites*, including *T. subbullatus*, and "*Eutomoceras*" *sandlingense* (= *Discotropites sandlingense*), *Sagenites* cf. *S. erinaceus*, and *Nautilus triadicus*. This fauna was considered equivalent to that of the *Tropites subbullatus* and *Trachyceras aon* zones of the Tyrolean Alps and was assigned an early Karnian age. Later, in 1898, Smith considered that all of the forms previously assigned to *Trachyceras* s.l. from the Hosselkus limestone of Shasta County belonged to the subgenus *Protrachyceras* and subsequently several new species of this subgenus were established for these forms. It should be noted that in all of Smith's papers *Protrachyceras* is treated as a subgenus and the generic name *Trachyceras* is used interchangeably in an unrestricted sense.

In 1895 (p. 494) and in ensuing publications by Smith (1896, p. 395–396; 1898, p. 784–786) attention was drawn to the anomalous occurrence of *Trachyceras*-like forms in the same fauna with the genus *Tropites* in the Hosselkus limestone. In the Alpine region *Trachyceras* s.s. and *Protrachyceras* are not found above the lower Karnian while *Tropites* first appears in the upper Karnian. Relying in part on the views of Mojsisovics (1886, p. 148–149), Smith be-

[1] Publication authorized by the Director, U. S. Geological Survey.

lieved that whereas *Trachyceras* was endemic in the Mediterranean region, *Tropites* was probably indigenous to the Arctic-Pacific region. Further research on the Triassic ammonoids of North America led Smith, who was a strong proponent of biogenetic studies, to the conclusion that the genus *Tropigastrites* Smith, 1914, from the Anisian (Middle Triassic) of Nevada was the immediate progenitor of the Karnian *Tropites*. The absence or scarcity of *Tropigastrites* in the middle Triassic elsewhere in the world plus the wide variety of forms representing the genus *Tropites* in the Hosselkus limestone of Shasta County convinced Smith (1927, p. 27–28) that *Tropites* was indigenous to North America and that, following the concept of homotaxis, it probably appeared in North America somewhat earlier than it did elsewhere. Therefore, according to Smith, it was not unreasonable for the Californian *Tropites* to be associated with the usually older trachyceratids.

A single fragmentary specimen of a *Trachyceras*-like ammonite from the Tropites limestone of the Himalayas was reported by Mojsisovics (1896, p. 75), who noted the agreement between this occurrence and the association of trachyceratids with *Tropites* in California as reported by Smith. The anomaly in comparison with the Alpine section was attributed by Mojsisovics (1896, p. 108) to a late survival of *Trachyceras* in India and California. Smith (1898, p. 786), however, did not accept this viewpoint in regard to the California trachyceratids, arguing that this explanation for the occurrence together of

> . . . the Subbullatus fauna and *Trachyceras* . . . is more likely true of India, where the survival consists of [a] single species of genuine *Trachyceras*, but in California the fauna is almost too large to be a survival.

It should be noted that Mojsisovics' specimen, though resembling *Trachyceras* in its lateral sculpture, cannot be assigned with certainty to *Trachyceras* s.s., because the ventral portion of the shell is missing. An additional specimen tentatively assigned to *Trachyceras* s.s., plus three other specimens assigned to *Protrachyceras*, were reported from the Tropites limestone of Byans in the Himalayas by Diener (1906, p. 79). These forms were not considered by Diener (p. 190–191) indicative of an age earlier than that of the European *Tropites subbullatus* zone because of the occurrence of the genus *Trachyceras* " . . . in the Tropites beds of California, of undoubtedly Tuvalic age" (the time equivalent of the *Tropites subbullatus* zone) as reported by Smith. This interpretation of the Himalayan occurrence of trachyceratids did not provoke comment from Smith.

The argument by Smith that the trachyceratid fauna of the Hosselkus limestone of Shasta County is too large to be a survival into the *Tropites subbullatus* zone is worthy of further comment. The term "large" presumably refers to the number of different forms represented as well as to their abundance. Six specific names, *Trachyceras* (*Protrachyceras*) *lecontei* Hyatt & Smith, 1905, *T.* (*P.*) *shastense* Smith, 1904, *T.* (*P.*) *madisonense* Smith, 1927, *T.* (*P.*) *lindgreni* Smith, 1927, *T.* (*P.*) *beckeri* Smith, 1927, and *T.* (*P.*) *californicum* Smith, 1927, have been established for the forms assigned to *Protrachyceras*. Listed in this order these "species" form an intergrading morphologic series from compressed forms with delicate strigate ornamentation to relatively robust forms with coarse ornamentation on the mature shell. On the most compressed forms, like those included by Smith in *P. lecontei*, the ornamentation consists of very fine, somewhat irregular, radial ribs transected by numerous longitudinal ridges of varying strength that bear small tubercles where they cross the ribs. This type of ornamentation apparently persists through maturity in these forms, but on the more robust specimens it is succeeded at maturity by a coarser and strikingly different type of sculpture. On the flanks of the mature robust shells the strigate ornamentation of the inner whorls is supplanted by coarse fold-like radial ribs without tubercles. Prominent spines are commonly developed on the ventrolateral shoulders where the lateral ribs bifurcate and tubercular longitudinal ridges are retained only on the ventral surface. Although the tendency toward coarse lateral ribbing is already developed on the inner whorls, the strigate ontogenetic stage is evident on the penultimate whorl of even the most robust individuals, like that selected by Smith as the holotype of *P. californicum*. As these intergrading forms occur together at the same stratigraphic horizon, it seems preferable to include all of them in a single species designated by the earliest specific name pro-

posed, i.e., *P. shastense* Smith, 1904. Thus, while these forms assigned by Smith to *Protrachyceras* show considerable morphologic variation, they are regarded here as only one biologic entity. Furthermore, although this emended species is probably a trachyceratid, it is considerably different in morphology from the species of *Protrachyceras* that characterize the Ladinian and lower Karnian of Europe.

The forms assigned by Smith to various new species and subgenera of *Clionites* may have also been considered as giving the Hosselkus fauna a trachyceratid aspect, though these forms have little in common with the typical species of this genus associated with *Trachyceras* s.s. in the lower Karnian of the Alps, as has been pointed out by Johnston (1941, p. 449) and by Spath (1951, p. 51). Other than these forms there is nothing in the Hosselkus fauna which could be construed as representing an abundant "*Trachyceras* fauna." A study of Smith's collections at Stanford University and at the U. S. National Museum in addition to the collections made by the writer from the Hosselkus limestone of Shasta County failed to produce any *Trachyceras*-like forms not previously described by Smith, or for that matter, any fossils indicative of the early Karnian faunal zones of *Trachyceras aon* or *T. aonoides*.

The characteristic species associated with the forms assigned to *Protrachyceras* by Smith, such as *Discotropites sandlingensis*, *Paratropites sellai*, *Metatirolites foliaceus*, *Sagenites herbichi*, and *Tropites* similar to *T. subbullatus*, all indicate an equivalence with the fauna of the Alpine late Karnian *Tropites subbullatus* zone. Consequently the apparently anomalous association of *Trachyceras* with *Tropites* in California can not be explained by assuming an early arrival of *Tropites* as suggested by Smith, but is due instead to the supposed occurrence of *Trachyceras* in an assemblage otherwise comparable to that of the *Tropites subbullatus* zone.

As early as 1896 (p. 396) the ammonite-bearing strata of the Hosselkus limestone in Shasta County were correctly assigned by Smith to the *Tropites subbullatus* zone, but two local subdivisions of this zone were recognized. The forms assigned to *Protrachyceras* and certain other ammonites, including several of Smith's species of *Tropites*, were found to be restricted to the lower portion of the zone for which the name "*Trachyceras* beds" was adopted (Smith, 1904, p. 360). Later, these beds were more formally designated the "*Trachyceras* subzone" (Smith, 1927). The upper subdivision of the *Tropites subbullatus* zone of the Hosselkus limestone was characterized by other forms, including several groups of *Tropites* and *Juvavites*, and was named by Smith the "*Juvavites* subzone."

Until recently, published accounts on the Late Triassic faunas of the western United States have been nearly restricted to Smith's various papers, which are largely based on collections from the Hosselkus limestone of Shasta County. As a result the fauna and stratigraphic interpretation of the Hosselkus limestone as described by Smith has been taken as more or less the standard for the Karnian Stage of the marine Upper Triassic in the United States. For example, the zonation adopted by Smith, including the "*Trachyceras* subzone" of the *Tropites subbullatus* zone, is reproduced by Reed (1943, p. 104). The occurrence of *Trachyceras* in the *Tropites subbullatus* fauna of western North America is cited by Diener (1925, p. 117) and remarked upon by Neaverson (1955, p. 426). One of the species referred to the subgenus *Protrachyceras* by Smith has been illustrated under the generic name *Trachyceras* by Hanna & Hertlein (1943, fig. 60-4, 60-12). *Trachyceras* (*Protrachyceras*) *shastense* from the *Tropites* zone in California is given by Shimer & Shrock (1944, p. 579) as an example of the genus *Trachyceras*. In this same publication, incidentally, the type species of *Trachyceras*, although designated as *Ammonites aon* Münster by the original author of the genus (Laube, 1869, p. 16), is given as "*Trachyceras chiesense* Mojsisovics," which was considered as a possible, but undesirable, type species for the subgenus *Protrachyceras* by Smith (1904, p. 388; 1927, p. 78) and by Hyatt & Smith (1905, p. 193–194). These examples from several general reference works on stratigraphy and paleontology serve to show that Smith's writings have been widely disseminated and that the genus *Trachyceras*, if not the fauna of the early Karnian *Trachyceras* zone of the Alps, is generally regarded as being present in the late Karnian "Tropitan fauna" of the western United States.

THE INTERREGIONAL "*Trachyceras* ZONE" IN THE WESTERN UNITED STATES

In the sequence of faunal zones recognized in the Middle and Upper Triassic of the Alps, which is generally regarded as the interregional standard for rocks of this age, *Trachyceras* s.s. is restricted to the *Trachyceras aon* and *T. aonoides* zones. As a result these two early Karnian zones are often referred to less formally as the "*Trachyceras* zone" or, in the terminology applied by Spath (1934, p. 39), they represent the Trachyceratan Age.

The most fossiliferous exposures of the early Karnian *Trachyceras* zone known in North America are in South Canyon on the west side of the New Pass Range, Nevada. The fauna from this locality has been described by Johnston (1941) and contains many elements closely related to species typical of the Alpine lower Karnian, including the following:

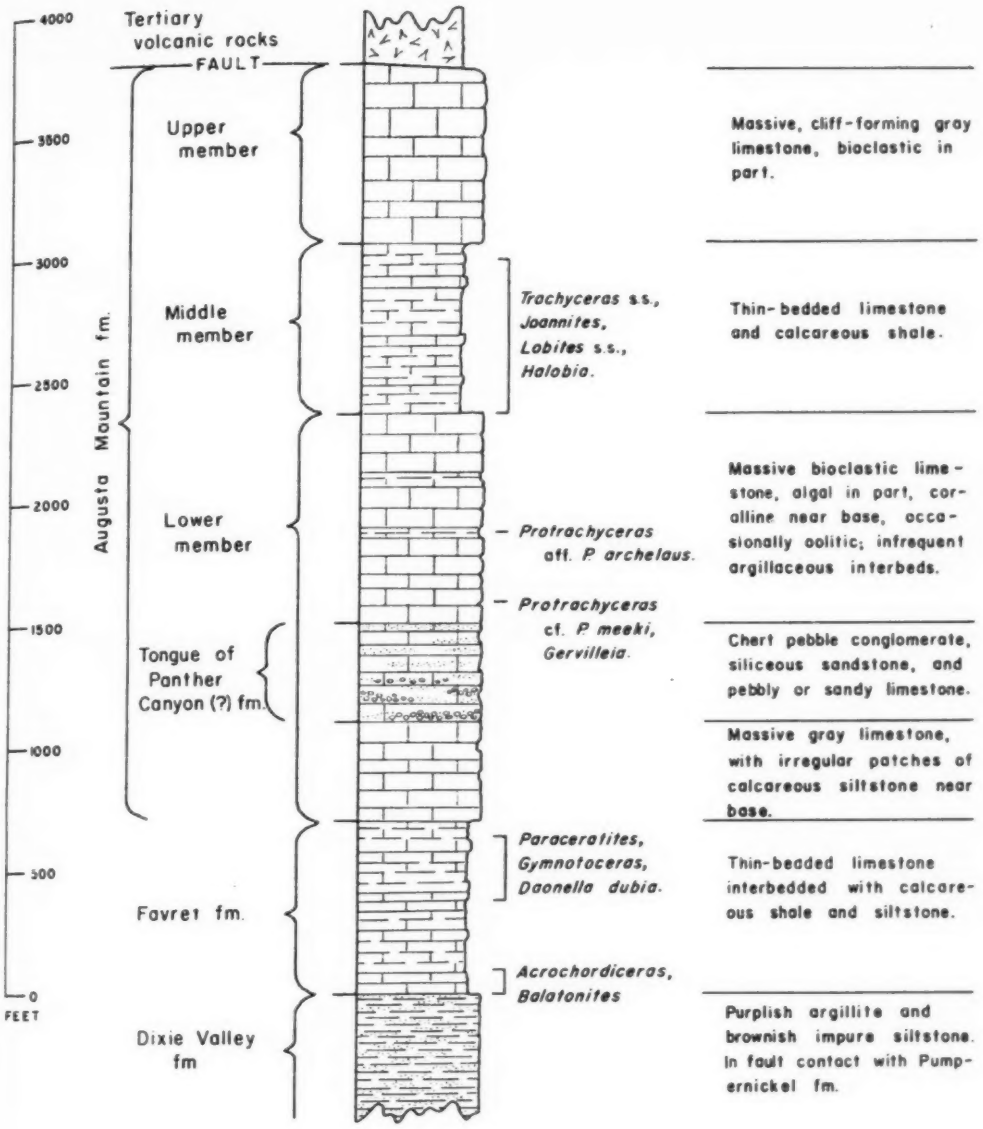
Trachyceras (*Trachyceras*) cf. *T.* (*T.*) *aonoides* Johnston (not Mojsisovics)
T. (*T.*) *desatoyense* Johnston
T. (*T.*) *bispinosum* Johnston
Joannites jocobus Johnston [closely resembling *J. klipsteini* Mojsisovics]
Cladiscites (*Procladiscites*) *rogersi* Johnston [closely resembling *C.* (*P.*) *gemmellaroi* Mojsisovics]
Arcestes (*Proarcestes*) cf. *A.* (*P.*) *gaytani* Klipstein
Lobites (*Lobites*) *carinatus* Johnston [resembling *L.* (*L.*) *beneckei* Mojsisovics]
Clionites wheeleri Johnston [resembling *C. torquati* Mojsisovics]
C. reesidei Johnston [resembling *C. valentini* Mojsisovics]
Sageceras cf. *S. haidingeri* (Hauer)

These species occur within a stratigraphic thickness of about 700 feet and may represent both the *Trachyceras aon* and *T. aonoides* zones. Unfortunately the variety of forms represented in the stratigraphically controlled collections made by the writer at this locality is not sufficient to separate the two zones, if both of them are present.

The sequence of faunas in the section exposed at South Canyon also indicates an early Karnian age for the beds containing this *Trachyceras* fauna because these beds conformably overlie strata of late Middle Triassic age. Diagnostic fossils have not been found in the superjacent strata and hence the upper limit for the age of the *Trachyceras*-bearing strata in terms of the European faunal zones cannot be determined. However, the lithologic unit containing the *Trachyceras* fauna in the New Pass Range is correlated with the middle member of the Augusta Mountain formation, which is overlain by several thousand feet of strata also regarded as Karnian in age in the Mount Tobin quadrangle about 25 miles to the north (Muller, Ferguson, & Roberts, 1951). The faunal and lithologic sequence of the Triassic rocks exposed in South Canyon in the New Pass Range and the suggested correlation of these rocks with the formational units recognized in the upper-plate facies of Triassic rocks in the Mount Tobin quadrangle is illustrated in Text-fig. 1. The name "Red Rock limestone" applied by Johnston (1941, p. 448) to the massive carbonate rocks overlying the *Trachyceras*-bearing beds in South Canyon is undesirable not only because this name as a formational designation has been preoccupied several times but also because the suggested correlation with the Red Rocks of the West Humboldt Range cannot be demonstrated.

The representatives of *Trachyceras* s.s. are the most abundant elements in the *Trachyceras* fauna of the New Pass Range and show a wide range of variation. The species present, although probably not conspecific, are closely related to the forms from the early Karnian of the Alps. This is adequately shown by Johnston's description of their ornamentation. However, the simple ceratitic nature of their suture lines, with nearly undivided saddles, as described and illustrated by Johnston, would appear to be distinctly different from the sutures of the Alpine forms. Both of the suture lines illustrated by Johnston (1941, p. 472–473, fig. 3H, 3I) are of weathered specimens, described as having been lost, which were originally assigned to *Trachyceras* (*Trachyceras*) cf. *T. aonoides*. The sutures of less weathered specimens prepared by the writer are illustrated by Text-fig. 2. These are much more complex and agree quite well with Alpine examples of *Trachyceras* s.s. in the degree of crenulation, proportions of the various elements, and in the tendency for the principal saddles and lobes to curve away from the venter towards their tips.

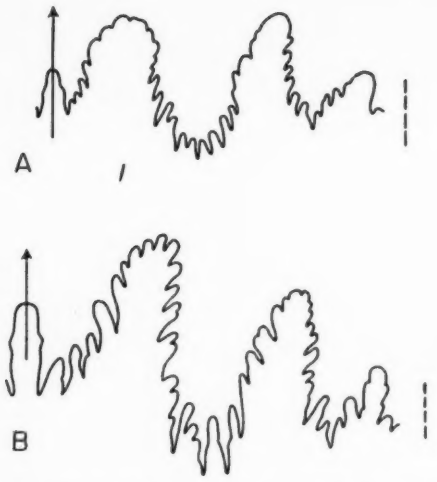
Although Johnston (1941, p. 481) recognized that the beds containing *Trachyceras* s.s. in the New Pass Range are equivalent to the Alpine *Trachyceras aon* or *T. aonoides* zone and represent an older horizon than



GENERALIZED STRATIGRAPHIC COLUMN
OF THE MIDDLE AND UPPER TRIASSIC ROCKS
EXPOSED IN SOUTH CANYON, NEW PASS RANGE, NEVADA

TEXT-FIG. *1*—Generalized stratigraphic column of the Middle and Upper Triassic rocks exposed in South Canyon, New Pass Range, Nevada.

Smith's "*Trachyceras* subzone" in California, he chose to designate them as the "... *Joanites* zone in order not to cause confusion with J. P. Smith's *Trachyceras* subzone of the zone of *Tropites subbullatus*". Nevertheless the assignment of these beds to the *Trachyceras aon* and/or *T. aonoides* zones is both appropriate and desirable, for these zones have world wide utility as standard subdivisions of the Karnian



TEXT-FIG. 2—Suture lines of *Trachyceras* s.s. from the *Trachyceras aon* or *T. aonoides* zone at South Canyon, New Pass Range, Nevada. *A*, *Trachyceras* (*Trachyceras*) cf. *T. aonoides* Johnston, 1941 (not Mojsisovics, 1893), USNM 128316, somewhat weathered, X1.8. *B*. *Trachyceras* (*Trachyceras*) cf. *T. desatoyense* Johnston, 1941, USNM 128317, ×1.5.

stage. As these zones are often characterized less formally as the "*Trachyceras* zone," there are at present two faunal subdivisions of differing age in the Karnian stage of the western United States for which the generic name *Trachyceras* can be applied as an index. The "*Trachyceras* subzone" adopted by Smith in California as a subdivision of the *Tropites subbullatus* zone is not equivalent to any part of the interregional "*Trachyceras* zone" (zones of *Trachyceras aon* and *T. aonoides*) and it is therefore a homonym.

RECOMMENDED CHANGES IN NOMENCLATURE

In addition to being misleading as the name of a faunal subdivision of late Karnian rocks, the name *Trachyceras* is not appropriate for the biologic entity for which Smith used it. This holds true as well for the name *Protrachyceras*, which was employed by Smith for the forms from the Hosselkus limestone of Shasta County in its original status as a subgeneric designation under *Trachyceras*. Although no type species for *Protrachyceras* has been designated, the forms from the Hosselkus limestone assigned to this taxon by Smith are morphologically distinct from all of the 52 genosyntypes originally included in the subgenus by Mojsisovics (1893, p. 618–619, 623–645). Likewise the forms described by Smith are considerably different from *Trachyceras aon* (Münster), the type species of *Trachyceras* s.s. Accordingly a new monotypic genus, *Spirogmoceras* Silberling, n. gen., (*speira*, coil; *ogmos*, furrow; *keras*, horn; gender neuter), is established here for the species *Protrachyceras shastense* Smith (1904, p. 391–392, pl. 46, fig. 9–9a, pl. 48, fig. 3 [holotype]-4) as emended in this paper. The present lack of a type species for *Protrachyceras* will not influence the status of this new genus because Smith's species is not included in the original syntypic series of *Protrachyceras*.

The morphology of *Spirogmoceras shastense* differs from that of the genosyntypes of *Protrachyceras* in the following respects:

(1) Well defined longitudinal ridges form the dominant ornamentation, at least on the immature shell, and are present on the venters of all forms at maturity.
(2) The number of tubercles on the more compressed individuals greatly exceeds the number present on the genosyntypes of *Protrachyceras*.
(3) The ventral furrow is poorly developed and the tubercles on the spiral ridges bordering the furrow are not prominent.
(4) Even the most robust forms are more involute than most of the genosyntypes of *Protrachyceras*.
(5) The septa are complex and thoroughly ammonitic rather than ceratitic or subammonitic.

The generic reassignment of the species selected by Smith as the index for the lower of the two subzones recognized in the *Tropites subbullatus* zone of the Hosselkus limestone of Shasta County, California, requires a new name to replace Smith's "*Trachyceras* subzone." Rather than adopt the new generic name established here in place of *Trachyceras* in Smith's usage, the writer proposes using the species *Tropites dilleri* Smith, 1904, as the index for this subzone. *Tropites dilleri* is chosen because it is abundant and yet restricted to the beds included in Smith's "*Trachyceras* subzone," and it also expresses the close relationship between the fauna of this subzone and that described from the *Tropites subbullatus* zone of the Alps.

SUMMARY

The salient features of the foregoing discussion may be summarized as follows:

(1) The faunal zones of *Trachyceras aon* and *T. aonoides* can be recognized in the western United States and occupy there the same position in the succession of Middle and Upper Triassic faunal zones that they do in Europe.

(2) The examples of *Trachyceras* s.s. from the *Trachyceras aon* and/or *T. aonoides* zones of the New Pass Range, Nevada, are congeneric in all respects, including the details of their septa, with the characteristic European forms of this subgenus.

(3) The name "*Trachyceras* subzone" applied by Smith to one of the subdivisions of the *Tropites subbullatus* zone recognized in the Hosselkus limestone of Shasta County, California, is an undesirable homonym of the "*Trachyceras* zone" in its acepted usage as a generalization for the *Trachyceras aon* and *T. aonoides* zones.

(4) The forms from the Hosselkus limestone of Shasta County assigned by Smith to the subgenus *Protrachyceras* of the genus *Trachyceras*, all of which are placed here in synonomy with *P. shastense* Smith, are considerably different from *Trachyceras* s.l. and are transferred to a new genus, *Spirogmoceras*.

(5) The fauna of Smith's "*Trachyceras* subzone" shows the closest agreement with that of the Alpine *Tropites subbullatus* zone and contains no elements characteristic of older European zones.

(6) The name *Tropites dilleri* subzone is suggested as a replacement for Smith's "*Trachyceras* subzone."

ACKNOWLEDGMENTS

The author wishes to thank Professor Siemon W. Muller and Dr. John B. Reeside, Jr., who critically reviewed the manuscript.

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MANUSCRIPT RECEIVED MAY 7, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1154, PL. 121, SEPTEMBER 1956

AN ATURIA FROM EASTERN CUBA

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ABSTRACT—A representative of *Aturia cubaensis* (Lea) is described from the Oligocene in the central part of the province of Oriente. Very few Tertiary nautiloids are known from Cuba.

IN AN excavation made for a new highway in eastern Cuba, a well preserved nautiloid was found in light-colored limestone. This specimen was made available to us by Dr. G. Arthur Cooper of the U. S. National Museum. Also, we are indebted to Drs. Pedro J. Bermúdez and Noel K. Brown, Jr., for advice on geologic and geographic details.

The preserved portion of the specimen under consideration is completely septate, and unfigured fragments which fit onto the adoral end of it indicate that the phragmocone attained a diameter of at least 150 mm. When complete, with the body chamber, the shell was at least 250 mm. in diameter. Where the internal mold is 50 mm. high, its corresponding width measures 34 mm., and the test is about 0.4 mm. thick along the venter. On the external surface there are fine growth lines which show a rounded ventral sinus.

The proportions of the conch, and all of the other ascertainable features, coincide with those of the two fragmentary representatives of *Aturia cubaensis* (Lea) that have been described previously. The holotype of that species probably came from the Lower Miocene Güines limestone near the city of Matanzas, about 50 miles east of Habana; and recently Miller & Downs (1950, p. 11–12, pl. 9, fig. 3,4) described a similar specimen which Bermúdez obtained from that horizon and locality. Cuban aturias have also been listed from the Middle Eocene at Jicotea, 100 miles east of Matanzas, and from the Upper Oligocene or Lower Miocene at Habana.

The specimen under consideration was found some 400 miles to the east-southeast of Matanzas near Barajagua, a small village between Holguín and Cueto, in the central part of the province of Oriente. According to Keijzer (1945, geologic map) the strata there are the Oligocene and Miocene "Nipe series." Bermúdez (1950, p. 285–286) believes that the Nipe fauna lists indicate an Oligocene age. This aturia is preserved in yellow dense fragmental limestone which contains other fossils, including orbitoid foraminifers. The specimen has been deposited in the U. S. National Museum.

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MANUSCRIPT RECEIVED FEBRUARY 2, 1956

EXPLANATION OF PLATE 121

FIG. *1–4*—*Aturia cubaensis* (Lea). Three views of a specimen from the Oligocene Nipe beds near Barajagua, between Holguín and Cueto, Oriente, Cuba, ×1 (fig. *1,2*) & ×1¼ (fig. *3*); and lateral view of the holotype, probably from the Lower Miocene Güines limestone, near the city of Matanzas, northwestern Cuba, ×2. Photographs retouched by Messrs. Lee Allen and Frederick Leach.

1

3

2

4

1

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1155–1157, PL. 122, 2 TEXT-FIG., SEPTEMBER 1956

AN ATUROIDEA FROM AUSTRIA

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ABSTRACT—A well preserved internal mold is described from the Mattseer Grünsanden some 20 km. north of Salzburg. It appears to be referable to *Aturoidea brunlechneri* (Frauscher) of the Eocene at Guttaring, 150 km. to the southeast.

THE generic affinities of *Aturia brunlechneri* Frauscher have long been uncertain for that species was based on a single large crushed fragmentary specimen from the Eocene of south-central Austria. Both Frauscher (1895, p. 199) and Spath (1927, p. 428), recognized that it appears to be close to *Nautilus parkinsoni* Edwards, the type species of *Aturoidea*. Nevertheless, the published illustration suggested to Miller & Thompson (1935, p. 563) and to Miller (1947, p. 70) a relationship with *Deltoidonautilus*.

In addition to the holotype of his species, Frauscher had available for study a large internal mold from the Mattseer Grünsanden, and he regarded it as perhaps conspecific. That individual was never illustrated or described, and we have not seen it. However, recently Dr. W. H. Easton spoke of a fine, large Austrian specimen in the collections at the University of Southern California, which at our request he sent us on loan. The label which accompanies it indicates that it came from the same general horizon and locality as the one which Frauscher recorded from Mattsee. It is composed of limestone which contains so much glauconite that it can be called "greensand." All in all, it seems likely that this individual, an internal mold, is conspecific with the similar one Frauscher had from the same place and that both are referable to *Aturoidea brunlechneri*.

ATUROIDEA BRUNLECHNERI (Frauscher)

Pl. 122, fig. 1

Aturia Brunlechneri FRAUSCHER, 1895, Kärnten naturhist. Landes-Mus., Jahrb., Bd. 23, p. 196–199, pl. 2.

Paraturia? brunlechneri SPATH, 1927, Ann. Mag. Nat. Hist., ser. 9, vol. 20, p. 428.

Deltoidonautilus? brunlechneri MILLER & THOMPSON, 1935, Jour. Paleont., vol. 9, p. 563.

Deltoidonautilus? brunlechneri MILLER, 1947, Geol. Soc. Amer., Mem. 23, p. 70.

Aturoidea? sp. MILLER, 1951, Mus. Congo Belge, Ann., sér. 8°, Sci. géol., vol. 8, p. 68.

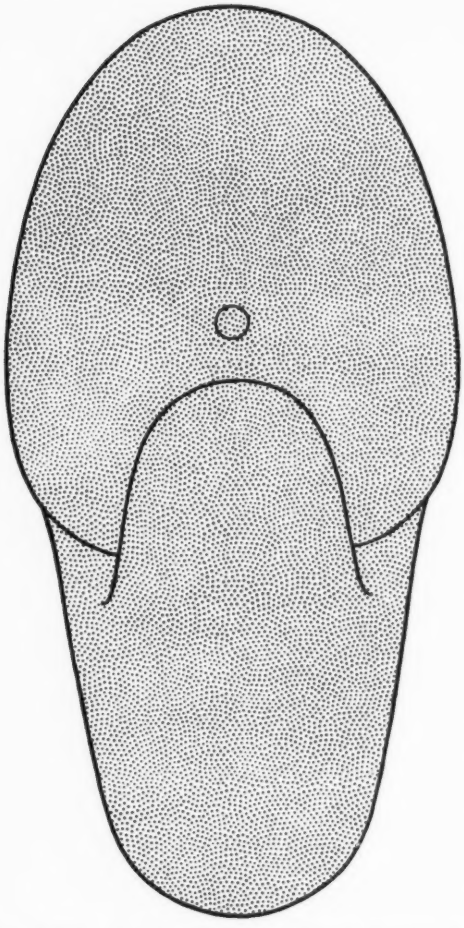
The specimen under consideration is well presevered and appears to be only slightly distorted. It is septate throughout and probably represents most of the phragmocone. At its adoral extremity there is a small portion of a septum, as is shown on the accompanying plate. The external test is not preserved, but the specimen retains portions of the shell material of the septa and a structure that appears to be an umbilical plug.

The overall measurement of this specimen is about 235 mm. The maximum height and width attained by the preserved portion of the conch are some 145 mm. and 110 mm. It is estimated that originally the width was something like ten per cent greater. The shape of the cross section is elucidated by Text-fig. 1.

No trace is retained of any surface makings the test may have possessed. There are 13 camerae in the adoral volution of the specimen. As shown by Text-fig. 2, the suture is

EXPLANATION OF PLATE 122

FIG. 1—*Aturoidea brunlechneri* (Frauscher). Lateral view of an internal mold from the Eocene Mattseer Grünsanden at Mattsee, some 20 km. north of Salzburg, Austria, ×¾. Photograph retouched by Frederick D. Leach.



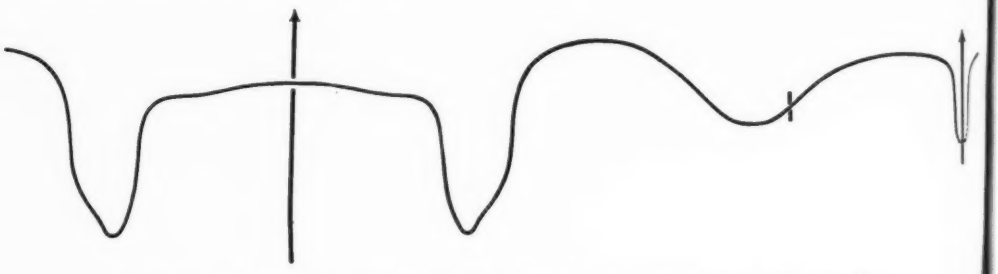
TEXT-FIG. 1—Diagrammatic ventral outline of *Aturoidea brunlechneri* (Frauscher), ×½.

typical for this genus and forms a total of five lobes, with the lateral ones being asymmetrically attenuate. The dorsal lobe was somewhat distorted during preservation so the details are not clear, but in the drawing it has been restored. The siphuncle is located slightly ventrad of the dorsum, the bottom of the impressed zone.

Remarks.—The large size of this specimen is not particularly noteworthy for most congeneric forms are known to have attained comparable dimensions. In the type species of the genus, *A. parkinsoni* (Edwards) of the Lower Eocene London clay, the phragmocone reached a maximum size at least some 50 per cent greater than that of the specimen we are studying. It may be presumed that this Austrian individual had a body chamber about half a volution in length and attained a maximum overall measurement of more than 350 mm.

With the exception of some primitive Cretaceous forms, all known representatives of the genus *Aturoidea* look very much alike. Species are differentiated on the basis of slight variations, some of which may be a result of preservation and/or interpretation. The specimen under consideration is about average for the genus, and the narrow cross section which Frauscher attributed to the holotype is probably due to crushing. That specimen is fragmentary, but it retains the test and shows that the growth lines form a deep ventral sinus and on either side of it a broad rounded lateral salient.

The rock which comprises the Mattsee specimen under consideration consists of finely crystalline light-brown limestone containing about 40 per cent glauconite. There are scattered angular coarse grains of quartz and phosphate some 2 mm. in diameter. In addition, there are large foraminifers (orbitoids and other forms), up to about 10 mm. in diameter.



TEXT-FIG. 2—Diagrammatic representation of a complete suture of *Aturoidea brunlechneri* (Frauscher), ×½.

Occurrence.—Mattseer Grünsanden at Mattsee, Austria, some 20 km. north of Salzburg. The species was originally described from the Eocene near Guttaring, south-central Austria, about 150 km. southeast of Mattsee.

Repository.—University of Southern California, Los Angeles, 3575.

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MANUSCRIPT RECEIVED FEBRUARY 2, 1956

NOTICE ON ZOOLOGICAL NOMENCLATURE

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the undermentioned names:

Items included in Parts 1 and 2 of Volume 12 of the Bulletin of Zoological Nomenclature, scheduled for publication on June 12, 1956:

1. *Paradoxides* Brongniart, 1822, validation of; *Olenus* Dalman, 1827, designation of type species for, in harmony with accustomed usage; *paradoxus* Linnaeus, 1759 (*Entomolithus*) suppression of; PARADOXIDEN Emmrich, 1844 (wrongly based on *Olenus*), suppression of (Class Trilobita) [Z.N.(S.) 623].

2. *tuberculatus* Hall, 1859 (Acidaspis), validation of; *Acantholoma* Conrad, 1840, suppression of (Class Trilobita) [Z.N.(S.) 998].

3. *Protopeltura* Brögger, 1822 (Class Trilobita), designation of type species for, in harmony with accustomed usage [Z.N.(S.) 1034].

Items in Part 2 of Volume 12 of the Bulletin, scheduled for publication on June 12, 1956:

1. *Trinucleus* Murchison, 1839, validation of; *tuberculatus* Link, 1807 (Trinucleus), suppression of (Class Trilobita) [Z.N.(S.) 926].

2. *Illaenus* Dalman, [1827], protection of by suppression of *Cryptonymus* Eichwald, 1825 (Class Trilobita) [Z.N.(S.) 1068].

Item in Part 3 of Volume 12 of the Bulletin, scheduled for publication on June 26, 1956:

1. *Asaphus* Brongniart, 1822, validation of, and designation of a type species for, in harmony with accustomed usage; *cornigerus* Schlotheim, 1820 (*Trilobites*), suppression of (Class Trilobita) [Z.N.(S.) 636].

Item in Double-Part 7/8 of Volume 12 of the Bulletin, scheduled for publication on August 24, 1956:

1. *Anchisauripus* Lull, 1904, and *Otouphepus* and *magnificus* (*Otouphepus*), both of Cushman, 1904, suppression of (Class Reptilia Theropoda [*Ichnites*]) [Z.N.(S.) 1081].

Any specialist who may desire to comment on the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address 28 Park Village East, Regent's Park, London, N.W. 1, England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the present notice.

Extracted from notes from FRANCIS HEMMING, Secretary to the International Commission on Zoological Nomenclature, dated June 2, June 12, and August 15, 1956.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, p. 1158, SEPTEMBER 1956

PALEONTOLOGICAL NOTE

VALUE OF MOLLUSKS IN THE ZONATION OF THE "PEORIAN" LOESS OF NEBRASKA

LARRY FRANKEL
University of Connecticut

In Nebraska, it has not been possible to divide the "Peorian" loess into Iowan and Tazewell portions successfully because Tazewell and Cary tills are not present. Therefore, the loess lying above the Sangamon soil and below the Brady soil is considered to be "Peorian" (Schultz & Stout, 1945; Schultz, Lueninghoener & Frankforter, 1951).

Vertebrate fossils are found in the Sangamon and Brady soil zones, but other than for insignificant fragments, none has been found in the "Peorian" loess (Schultz, Lueninghoener & Frankforter, 1951). Mollusks, therefore, are the only fossils common in this material.

A. Byron Leonard's separation of the Peoria member of the Sanborn formation (="Peorian" loess of Nebraska) into lower (Iowan), transitional, and upper (Tazewell) zones by using typical mollusk assemblages (1951, 1952) created much interest in an effort to do the same in Nebraska. Unfortunately, preliminary attempts to utilize these mollusks in dividing the "Peorian" loess of Nebraska have not been successful. Many of the species reported to be restricted to certain zones in the Peoria member of the Sanborn formation in Kansas are not so limited in the deposits examined in Nebraska.

Succinea avara is not restricted to a lower and transitional zone as it is reported to be in Kansas, but instead it is found throughout the "Peorian" and post-"Peorian" Pleistocene deposits. Similarly, *Succinea grosvenori* is not restricted to a transitional and upper zone, nor is *Succinea ovalis* restricted to the upper part of the "Peorian" loess as they are reported to be in Kansas. *Lymnaea parva* is likewise not restricted to the lower "Peorian," but instead, it is found throughout the "Peorian" and post-"Peorian" Pleistocene materials. *Vertigo modesta*, which is said to be absent in the lower "Peorian" of Kansas, is present, although not abundant, nor common, in the lower "Peorian" of Nebraska; it has also been found in the post-"Peorian" Pleistocene sediments.

The stratigraphic occurrence of other species reported to be restricted to certain zones in Kansas is not completely known at the present time. There is some evidence, however, that *Columella alticola* is not restricted to the upper part (Tazewell) of the "Peorian" loess as it is reported to be in Kansas, and there is some doubt as to whether *Discus shimeki* appears after *Discus cronkhitei*.

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MANUSCRIPT RECEIVED APRIL 9, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1159–1164, PL. 123, 1 TEXT-FIG., SEPTEMBER 1956

A RESTUDY OF THE SILURIAN NAUTILOID GENUS *PRISTEROCERAS* RUEDEMANN

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Ohio State University, Columbus, Ohio

ABSTRACT—The types of the breviconic nautiloid genus *Pristeroceras* Ruedemann are redescribed, and five additional specimens from the Syracuse formation (Upper Silurian) of New York are described for the first time. Available evidence suggests that *Pristeroceras* should be included in the discosoroid family Phragmoceratidae rather than in the onococeratid family Hemiphragmoceratidae. Stratigraphically older representatives of *Pristeroceras* have simple apertures, which tend to become more complex with time.

IN 1925, Ruedemann proposed the name *Pristeroceras* for an assemblage of poorly preserved breviconic nautiloids with visored apertures collected from the Upper Silurian Bertie waterlime at Buffalo, New York. Ruedemann's specimens were assigned to a single species, *P. timidum;* no other specific groups have subsequently been recognized, nor have additional specimens referable to the genus been reported from any other locality. Furthermore, the state of preservation of the types makes it difficult to relate *Pristeroceras* to any of the nautiloid families presently recognized. In 1951, however, in connection with a general stratigraphic study of the Salina group, the junior author collected several rather well preserved nautiloids which probably belong to *Pristeroceras.* These specimens differ in certain respects from the types and were collected from a portion of the section considerably below the Bertie. Consequently, we believe that a description of them is appropriate at this time, together with a restudy of the generic group to which they apparently belong.

The Upper Silurian Salina group of central and western New York is 700 to 900 feet thick, and is divided into four formations (Leutze, 1956), to which the names Vernon, Syracuse, Camillus, and Bertie are applied in ascending order. In eastern New York, the Salina consists of only the thin Brayman shale, a facies equivalent of the Camillus and Bertie, which lies directly upon deformed strata of Ordovician age (Fisher & Rickard, 1953).

Until recently (Leutze, 1956), the Syracuse formation, which is about 140 feet thick, was recognized only in the subsurface, its exposed portions being included with the overlying Camillus shale. However, in 1951, foundation excavations in Syracuse, New York, exposed unweathered portions of the Syracuse formation so that it could be studied carefully at the surface. From several such sections, the junior author was able to collect fragmentary nautiloids which seem to belong in *Pristeroceras*, a genus previously known only from the Bertie.

Fossils are not abundant in Salina strata, and only a few cephalopods have been reported from the entire group. Representatives of *Hexameroceras* are known from the Vernon shale, and the Syracuse formation has yielded a questionable species of *Hexameroceras*, several unidentified orthoceracones and the specimens of *Pristeroceras* described in the present report. To the best of our knowledge, no fossil cephalopods have been collected from the Camillus shale, but the superjacent Bertie has produced a number of specimens, referable to "*Orthoceras*," *Dawsonoceras*, *Hexameroceras*, *Gomphoceras*, *Phragmoceras*, *Phragmocerina*, *Pristeroceras*, and *Trochoceras*. This is not a particularly large assemblage for such an extensive group of strata, but it is a striking fact that the known Salina cephalopod fauna is dominated by breviconies with visored apertures. The modified apertures which characterize these cephalopods apparently developed independently in two different stocks and representatives of both groups are found together in rocks of Silurian age in North America and Europe.

We are indebted to the staff of the New York State Museum, particularly Dr. D. W.

Fisher and Mr. C. F. Kilfoyle, for loaning us the types of *Pristeroceras timidum* for direct comparison. Professor Newton E. Chute, of Syracuse University, aided us by sending several specimens of *Pristeroceras* which had been deposited at Syracuse, and we have profited from a discussion of several problems with Dr. R. H. Flower, of the New Mexico State Bureau of Mines.

SYSTEMATIC DESCRIPTIONS

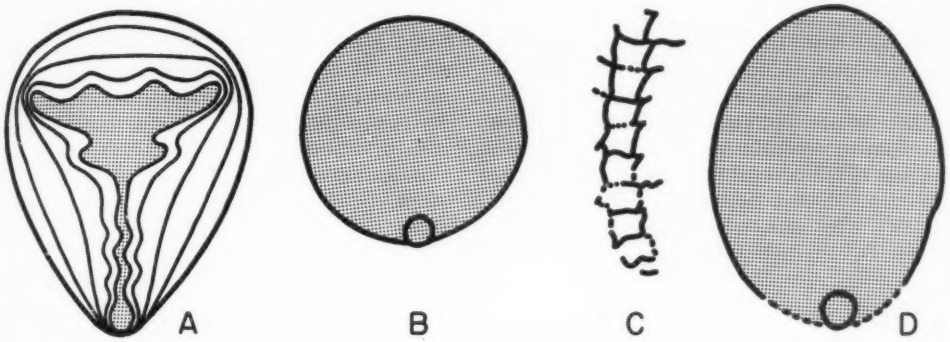
Genus PRISTEROCERAS Ruedemann, 1925

Type species: *Pristeroceras timidum* Ruedemann

Pristeroceras RUEDEMANN, 1925, New York State Mus. Bull. 265, p. 57–61; FOERSTE, 1926, Denison Univ. Bull., Jour. Sci. Labs., vol. 21, p. 363.

Although this genus was established more than thirty years ago, we still have a great deal to learn about it. It was erected to include eleven specimens, all poorly preserved, from the Bertie waterlime at Buffalo, New York. We have studied nine of these specimens which are deposited in the New York State Museum, and Ruedemann's illustrations of two specimens now in the Buffalo Museum appear to be adequate. As far as we can ascertain, Ruedemann based his generic description upon all eleven specimens, and did not select any certain ones as being especially typical of the group as a whole. Consequently, it may well be that all of the forms originally included, which now constitute the generic types, are not congeneric, and a revised description should perhaps be prepared which is based upon only those specimens which definitely belong together in the same genus. Unfortunately, the ones which obviously belong together for the most part elucidate virtually the same portions of the conch, and important information concerning the internal structures cannot be derived from them. With these limitatilns in mind, we have prepared the following diagnosis of *Pristeroceras* with reference only to those of the original eleven types which we are illustrating as fig. 3,10,11 and 12 on Pl. 123. In succeeding paragraphs, we will discuss the other specimens included by Ruedemann in the order of their probable association with *Pristeroceras*.

The four specimens upon which we are basing our revised diagnosis are body chambers filled with dark gray dolomitic limestone covered with a carbonaceous film which represents a residue of the shell material. These body chambers have been variously distorted but almost certainly they were originally subovoid in shape, the maximum lateral diameter being about five-sixths the maximum dorso-ventral diameter (exclusive of the hyponomic "spout"). Ventrally, the adoral portion of the body chamber is produced as a prominent, spout-like process, the length of which may be as much as one-third that of the maximum dorso-ventral diameter. The aperture is terminal, and constricted in such a manner as to resemble that of *Hexameroceras*. Dorsally, the aperture is rather wide and is symmetrically lobate. The margin of the dorsal portion of the aperture is indented by seven salients which include between them six sinuses, three on either side of the dorso-ventral mid-line. The dorsal sinuses are broad, blunt and directed dorsad; the dorsolateral sinuses are longer than the dorsal pair, and their distal portions curve dorsad. The ventrolateral sinuses are broader and longer than the dorsal two but not as long as the dorsolateral ones. The portion of the aperture which lies between the lobate dorsal extremity and the proximal end of the hyponomic "spout" is very narrow, and is further constricted by four or five pairs of interlocking serrations. On the oral surface of the hyponomic "spout" the aperture widens somewhat, and presumably at the distal end of the process forms a suboval hyponomic sinus. The surface of the body chamber is marked by a series of concentric growth-lines. These are straight and directly transverse to the long axis of the conch adapically but are crenulated adorally as the apertural constrictions are developed. There appear to be three gradational stages in the development of the mature aperture indicated by the adapical-adoral sequence of growth-lines (see Text-fig. 1A). That is, at the adapical end of the body chamber the growth-lines record the presence of a wide, oval aperture. Adorally, the lateral and dorsal margins of the aperture appear to have become convex inward, resulting in the type of outline characteristic of *Phragmoceras*.



TEXT-FIG. 1.—Diagrammatic views of *Pristeroceras timidum* Ruedemann. *A*, The adoral growth-line sequence and mature aperture; *B*, a probable septal face exposing marginal siphuncle (?), ×1, NYSM 9562. *C*, An isolated siphuncle, ×1½, NYSM 9563. *D*, A probable septal face exposing marginal siphuncle (?), ×1, Buffalo Mus., Buffalo, N.Y.

The growth-lines indicate that only in the late stages of development did the apertural constrictions typical of *Pristeroceras* develop.

Included among the eleven specimens available to Ruedemann at the time he described *Pristeroceras*, there are three crushed forms which represent lateral views of a rapidly expanding, slightly curved, breviconic conch. None of these can definitely be associated with the type of aperture described above, but all of them show an adoral prolongation along the concave margin which represents an elongate hyponomic process. Furthermore, faint traces of a dorsally lobate aperture occur at the adoral end of two of these specimens. Consequently, like Ruedemann, we believe that these forms should be considered with the aperture bearing specimens upon which our revised diagnosis of *Pristeroceras* is based. These specimens are all of nearly the same size, having measured lengths of 48 to 55 mm. and maximum widths of 26 to 32 mm. No septa are visible in any of these forms, so it is not possible to determine the relative proportions between phragmocone and body chamber. The location of the hyponomic "spout" in the adoral portion of the concave side of the conch, seems to indicate conclusively that these are endogastric forms.

Two of the eleven types of *Pristeroceras* consist of subcircular impressions of what appear to represent septal faces. Since these cannot be associated with either the characteristic apertures or the somewhat questionable lateral views just described, we are not able to assign them any particular significance in the description or evaluation of *Pristeroceras*. Nevertheless, they were found in the same strata, presumably near the place from which the other specimens were collected, so we are including a brief description of them merely for the sake of completeness. The smaller of the two specimens, which we illustrate in Text-fig. 1B, is nearly circular in outline and 30 mm. in diameter. At the margin there is a subcircular structure slightly more than 4 mm. in diameter which may represent the siphuncle. The larger specimen, portrayed by Text-fig. 1D, is subelliptical in outline, having a maximum diameter of 41 mm., and a minor diameter of 30 mm. At the margin of one of the more acutely rounded ends, there is a subcircular structure similar to that displayed by the smaller specimen and this may also represent the siphuncular foramen. Although these cross-sections could easily belong to many of the other nautiloid genera known from the Bertie, it should be pointed out that they are not inconsistent in size with the measured average dimensions of forms definitely referable to *Pristeroceras*. However, only one of them, i.e., the one portrayed by Test-fig. 1D, has the laterally compressed cross section which we believe to be typical of *Pristeroceras*.

In his generic discussion Ruedemann

illustrates, but does not describe, an isolated siphuncle from the Bertie which he refers to *Pristeroceras*. This specimen, which is 22 mm. long, represents nine segments of a rather small siphuncle, and the adjadent portions of several septa. We were unable to section it for careful study, but an enlarged sketch of the specimen is included as Text-fig. 1C. This sketch makes it clear that the segments are only slightly expanded within the camerae, and suggests that the septal necks are strongly recurved and that the connecting rings thicken adorally. Interesting and significant as this specimen may be, however, it cannot definitely be associated generically with the other forms which are included in the types of *Pristeroceras*. The fact that Ruedemann attached so little importance to it seems to indicate that he was of the same opinion.

The nature of the generic types of *Pristeroceras* makes it difficult not only to describe the structure of a complete conch, but also to determine the ordinal or familial position of the genus itself. Considered alone, the mature aperture resembles that of *Hexameroceras*, differing only in the presence of interlocking serrations which constrict its ventral portion. Foerste (1926, p. 286, 364) noted this similarity, and Barrande (1867, p. 233) apparently included in *Phragmoceras panderi* (now the type of *Hexameroceras*) several forms with *Pristeroceras*-like serrations in the ventral portion of the aperture. Flower & Kummel (1950) do not mention *Pristeroceras* in their classification of the Nautiloidea.

Although we cannot conclusively demonstrate the affinities and taxonomic position of *Pristeroceras*, there are certain features exhibited by the types which suggest to us that the genus should be associated with the Phragmoceratidae rather than with the Hemiphragmoceratidae (which includes *Hexameroceras*). The prominent growth-lines on the body chamber of *Pristeroceras* indicate that during ontogenetic development the aperture passed through a stage reminiscent of *Phragmoceras*, and only in very late stages assumed the characters typical of *Pristeroceras*. Furthermore, the types are laterally compressed (rather than subcircular in cross section) which again suggests the Phragmoceratidae. If the isolated siphuncle is included with *Pristeroceras*, an association with *Phragmoceras* becomes even more convincing. This siphuncle has an outline more consistent with that of the discosorids, and does not show the nummuloidal character generally associated with the onococeratids. If *Pristeroceras* is, indeed, related to *Phragmoceras* and not to *Hexameroceras* it is a remarkable example of homeomorphy in Upper Silurian nautiloids.

PRISTEROCERAS TIMIDUM Ruedemann
Pl. 123, fig. 1–12

(?) *Phragmoceras panderi* [part] BARRANDE, 1867, Syst. Sil. du Centre de la Bohême, pt. 1, vol. 2, p. 233.

Pristeroceras timidum RUEDEMANN, 1925, New York State Mus., Bull. 265, p. 57–61, pl. 18, fig. 1–7; FOERSTE, 1926, Denison Univ. Bull., Jour. Sci. Labs., vol. 21, p. 362, 363; ——, 1929, Denison Univ. Bull., Jour. Sci. Labs., vol. 24, p. 374.

Only one species, *P. timidum*, has been referred to *Pristeroceras*, and its characters are covered in the generic diagnosis. However, we have five additional specimens from the Syracuse formation at Syracuse, New York, which appear to belong in this species. Four of these are body chambers which show the typical *Pristeroceras* aperture; the fifth specimen represents the adapical portion of a color-marked breviconic conch which was found in association with the others, but cannot definitely be placed in *Pristeroceras*.

All of the body chambers are of essentially the same size, and all of them are preserved in grayish brown dolomitic shale. The specimen portrayed by fig. 6 on Pl. 123 is subovoid in shape, with maximum dorso-ventral and lateral diameters of 20 mm. and 17 mm. respectively. The dorsal portion of the aperture consists of the six sinuses typical of *Pristeroceras*, although the dorsal salients are somewhat more prominent than in the types, and the ventrolateral salients are slightly curved laterally in their distal portions. The ventral slit-like portion of the aperture is constricted in its dorsal third by a single serrate projection. The remainder of the ventral aperture is unmodified. Near the ventral terminus of the hyponomic "spout," the apertural margins flare slightly and

presumably enclose a suboval hyponomic sinus at the tip of the process. Growth-lines are well developed on the surface of the specimen, and they exhibit the developmental sequence discussed in connection with the types.

The specimen illustrated by fig. 8 on Pl. 123 is similar in size to the one just described, having dorso-ventral and lateral diameters of 19 mm. and 18 mm. respectively and a length of at least 8 mm. It has apparently been distorted, but the amount of this distortion is difficult to assess. The dorsal portion of the aperture is similar to that of the types of *Pristeroceras*, and its ventral slit is modified by four serrate projections. The hyponomic "spout" is well developed, but not complete. The growth-lines are indistinct, but apparently similar to those of the types.

Figure 5 on Pl. 123 represents a body chamber with a dorso-ventral diameter of 18 mm. and a lateral diameter of 14 mm. The dorsal salient of the aperture is somewhat more prominent than in the types, or in the other Syracuse specimens with which it occurs. Part of this, however, may be due to lateral compression. The ventral slit is modified by only two pairs of serrations. Growth-lines are indistinct, but similar to those of the specimens just described.

An oblique view of the apertural face of a fourth specimen is presented by fig. 4 on Pl. 123. This form has a dorso-ventral diameter of about 19 mm., and an estimated lateral diameter of about 16 mm. The hyponomic process is constricted by at least three serrations. Growth-lines like those of the other specimens occur on the surface of the body chamber.

The fifth specimen which we are referring to *Pristeroceras timidum* represents a portion of a rapidly expanding, presumably breviconic conch 16 mm. long and 12 mm. high at its adoral end. This conch fragment consists of a carbonaceous film, which is crossed by three (and part of four) zig-zag transverse markings which appear to represent the color bands of the original test. On that portion of the test preserved, the color-markings form two prominent, adapically directed, V-shaped sinuses separated by similar adorally directed, V-shaped salients. As only part of one lateral zone is represented, it is not possible to determine the appearance of these markings on other portions of the conch. We cannot be certain, of course, that this form is assignable to *Pristeroceras*, but the apparent absence of other brevicones at this level in the Syracuse makes reference of this specimen to *Pristeroceras* seem plausible.

Discussion.—The Syracuse forms that we are studying are similar in general aspect to the types, but they differ from them in certain respects that deserve mention. The number of serrations added to the ventral, slit-like portion of the aperture is apparently more variable in the Syracuse specimens than it is in the types. The oldest specimen in our collection shows only one such ventral modification; the balance of the Syracuse forms have two, three, or four serrations, and all of the types have at least four and perhaps five. It might be argued that the number of serrations in the ventral portion of the aperture could serve to delimit specific groups. However, we prefer to interpret these differences as representing only minor stages in the gradational sequence of apertural modification in a single species, which, if carried to completion, might perhaps have resulted in complete closure of the ventral slit. If the color-marked individual is properly referable to *Pristeroceras timidum*, it would indicate that the surface of its conch was ornamented in a manner similar to that of many other cyrtoceraconic and brevoconic genera. The presence of this form, and other (see Ruedemann, 1925) color-marked specimens in the Bertie, together with ripple-marked clastic sediments, would suggest that the Salina sea was shallow enough so that considerable light penetrated to the bottom.

Occurrence.—Syracuse formation, (1) northwest corner James and Lodi Streets, (2) south side Erie Boulevard, between Bruce and Beattie Streets, Syracuse, New York.

Repository.—New York State Museum, Albany, New York, 10813 to 10816, inclusive.

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MANUSCRIPT RECEIVED APRIL 11, 1956.

EXPLANATION OF PLATE 123

All specimens illustrated on this plate are from the Salina group of New York. Those represented by fig. 1–3,7,10–12 are from the Bertie waterlime at Buffalo, N.Y.; those portrayed by fig. 4–6,8, and 9 are from the Syracuse formation at Syracuse, N. Y. The catalogue numbers are those of the New York State Museum, Albany, where the specimens are deposited.

FIG. *1–12—Pristeroceras timidum* Ruedemann. *1,2,7*, Lateral views of 3 crushed conchs, ×1 (9570, 9568, 9569). *3–6,8,10–12*, Apertural views of 8 specimens which represent only body chambers; *3,11*, ×2; *4–6,8,12*, ×1½; *10*, ×1 (9564, 10816, 10815, 10813, 10814, 9566, 9565, 9567). *9*, A fragmentary color-marked specimen doubtfully referred to *Pristeroceras*, ×3 (Syracuse Univ.).

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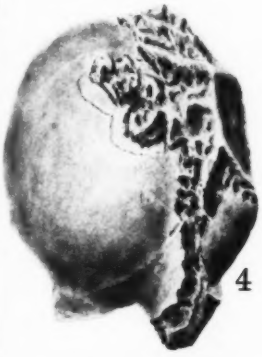
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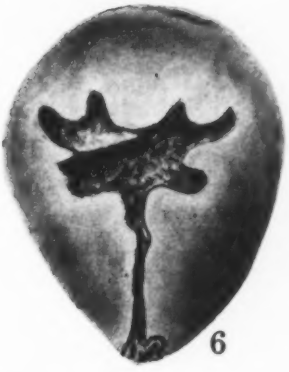
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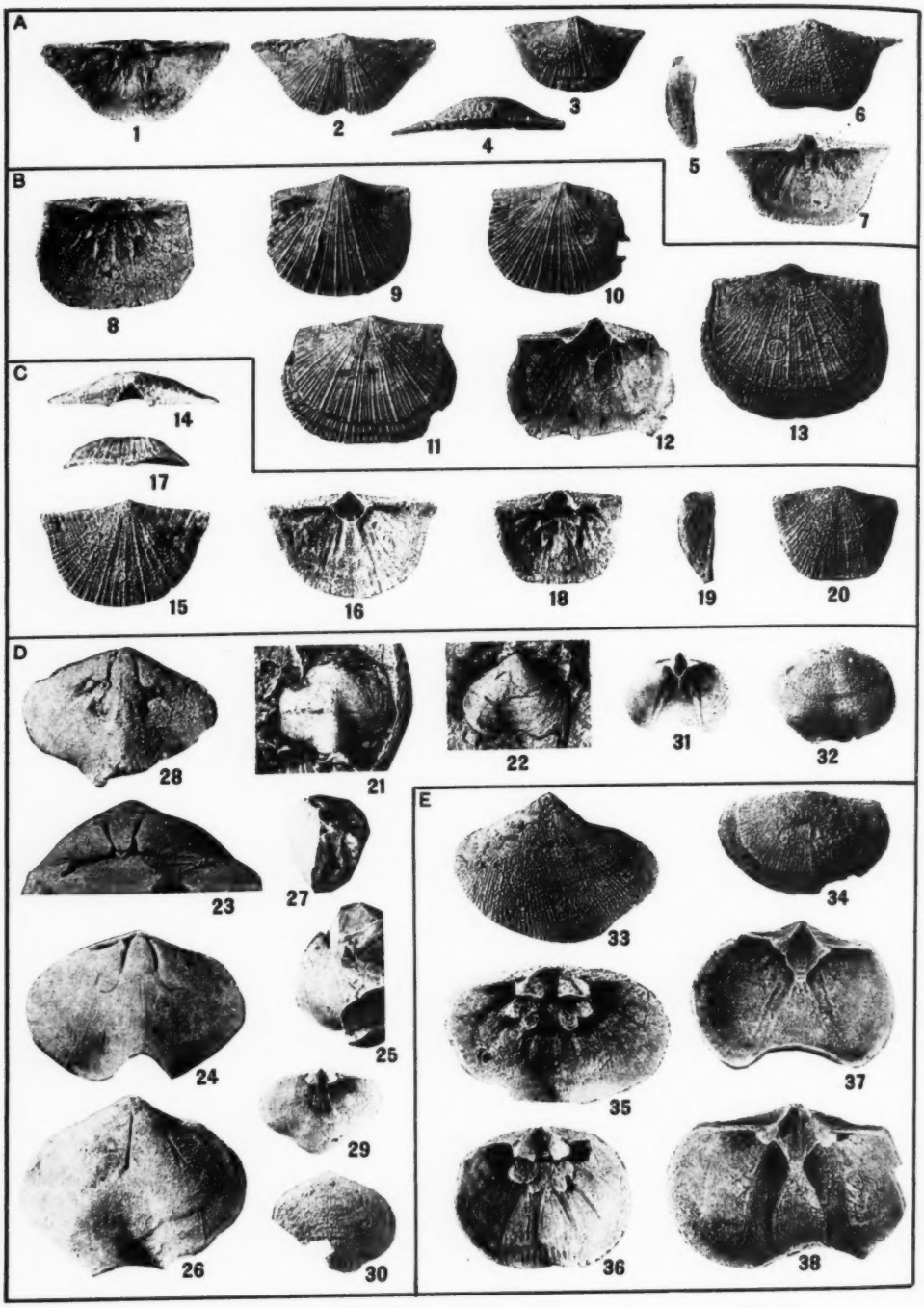
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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1165–1169, PL. 124, SEPTEMBER 1956

LOWER CANADIAN BRACHIOPODS FROM VIRGINIA[1]

ROBERT S. YOUNG
Virginia Division of Geology, Charlottesville, Virginia

ABSTRACT—Five species of brachiopods (two of them new: *Finkelnburgia logani* and *F. roanokensis*) from the Chepultepec-Stonehenge formation of the Appalachian Valley are described and illustrated.

INTRODUCTION

RECENT stratigraphic studies of the Ordovician Chepultepec-Stonehenge formation in northern Virginia show that this unit is considerably more fossiliferous than previously thought. From place to place, the fossils are silicified, and etching of limestone blocks from these localities has provided a well-rounded total faunal assemblage. The fauna includes cephalopods brachiopods, gastropods, trilobites, andtentaculitids. Of these, the tentaculitids and cephalopods have been reported upon

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EXPLANATION OF PLATE 124

A. *Finkelnburgia logani*, n. sp.

1,2, Interior and exterior of the brachial valve, ×2; holotype, USNM 126844a. *3*, Exterior of a small pedicle valve, ×2; paratype, USNM 126844b. *4,6*, Posterior and exterior views of another pedicle valve having mucronate cardinal extremities, ×2; paratype, USNM 126844d. *5,7*, Side and interior views of another pedicle valve, ×2; paratype, USNM 126844c.

Chepultepec limestone, 1.5 miles southwest of Mt. Clifton, Edinburg Quadrangle, Virginia.

B. *Finkelnburgia roanokensis*, n. sp.

8, Interior of the brachial valve showing adductor platforms, ×2; paratype, USNM 126843i, *9*, Exterior of a small pedicle valve, ×2; paratype, USNM 126843c. *10,11* Exterior views of two brachial valves, ×2; paratype, USNM 126843b, and holotype, USNM 126843h. *12*, Interior of the pedicle valve, ×2; paratype, USNM 126843a. *13*, Exterior of a large pedicle valve, ×2; paratype, USNM 126843e.

Chepultepec limestone, quarry one mile northeast of Roanoke, Virginia.

C. *Finkelnburgia buttsi* Ulrich & Cooper

14–16, Posterior, exterior and interior of a pedicle valve, ×2; holotype, USNM 91380h. *17–20*, respectively anterior, interior, side and exterior views of a brachial valve, ×2; paratype, USNM 91380e.

Chepultepec limestone, 2.1 miles northwest of Quicksburg, Mt. Jackson Quadrangle, Virginia.

D. *Syntrophina campbelli* (Walcott)

21,22, Plasticine replicas of the exterior of the brachial and pedicle valves, ×2, prepared from hypotypes, USNM 91614f and 91614j. *23,24*, Posterior and dorsal views of an impression of the brachial interior showing cardinalia, ×3; hypotype, USNM 91614g. *25*, Side view of the preceding specimen, ×2. *26*, Impression of the interior of the pedicle valve showing median septum, ×3; hypotype, USNM 91614a. *27*, Side view of the preceding, ×2.

Gasconade limestone, above and slightly north of Pine Hollow Spring, sec. 36, T. 28 N., R. 5 W., Eminence Quadrangle, Missouri.

28, Impression of the interior of the brachial valve, ×3, showing slits formed by supporting plates of cardinalia; paratype, USNM 52480d.

Chepultepec formation, Bunker Hill, 6 miles northeast of Rogersville, Tennessee.

29, Interior of a brachial valve showing cardinalia, ×2; hypotype, USNM 116749f. *30*, Exterior of same specimen (side broken after previous picture was taken), ×2. *31*, Interior of the pedicle valve, ×2, showing the spondylium and pallial trunks; hypotype, USNM 116749e. *32*, Exterior of another pedicle valve, ×2; hypotype, USNM 116749d.

McKenzie Hill limestone (360 feet above base), 950 feet west and 2050 feet north of SW corner sec. 26, T. 6 N., R. 14 W., Kindblade Ranch, Wichita Mountains, Oklahoma.

E. *Tetralobula delicatula* Ulrich & Copper

33, Exterior of the pedicle valve showing sulcus and costellae, ×3; syntype, USNM 91904b. *34*, Exterior of the brachial valve showing low fold, ×2; syntype, USNM 91904g. *35,36*, Interior of two brachial valves showing elevated adductor platforms, ×3; syntypes, USNM 91904i, 91904j. *37,38*, Interior of two pedicle valves showing spondylium and pallial trunks, ×3; syntypes, USNM 91904e, 91904f.

Chepultepec formation, 2.1 miles northwest of Quicksburg, Mt. Jackson Quadrangle, Virginia.

(Fisher & Young, 1955; Unklesbay & Young, 1956). Certain of the brachiopods were previously described by Ulrich & Cooper (1936, 1938); these are included in this paper.

Problems involving the stratigraphy of the basal Ordovician in Virginia and other Appalachian states have been presented by Butts (1940), Woodward (1951), and Unklesbay & Young (1956). There is no need to review these problems here. It is certain that the recent additions to the known lower Canadian fauna in Virginia will aid in regional correlations.

This paper would not have been possible without the generous aid of G. Arthur Cooper, U.S. National Museum, in editorial comments and preparation of photographs. The author gratefully acknowledges the interest and cooperation of William J. Sando, U. S. Geological Survey, in general discussions of Lower Ordovician stratigraphy and for locating collecting sites.

SYSTEMATIC DESCRIPTIONS

Phylum BRACHIODPODA
Order NEOTREMATA
Genus FINKELNBURGIA (Walcott), 1905

FINKELNBURGIA LOGANI, n. sp.

Pl. 124, A, fig. 1–7

Description.—Shell of medium size for the genus, width approximately twice the length, with the greatest width along the hinge; cardinal extremities angular and different specimens varying from slightly produced to mucronate; surface ornamented with costellae of unequal size, smaller ones predominating but without apparent regularity. Some specimens showing coarse growth lines.

Ventral valve slightly deeper than the dorsal, moderately convex in lateral profile with a slightly elevated and angular beak. Valve moderately inflated in the mid-region with gentle slopes to the cardinal extremities; interarea moderately steep, apsacline, and delthyrium prominent. Average length/width 2.36.

Dorsal valve marked longitudinally and medially by a shallow though well-defined sulcus which widens and deepens anteriorly to the front margin. Gently convex with greatest convexity at or a little anterior to the middle. Slopes to lateral margins gentle, those to cardinal extremities slightly concave. Wing points prominent. Average length/width 1.93.

Interior: Ventral valve with small spondylium which narrows anteriorly; short and slender median septum. Brachial valve with adductor platforms moderately developed.

Measurements in mm.:

	length	mid-width	hinge width
Holotype (brachial valve)	5.5	9.6	13.0
Paratype (pedicle valve 126844c)	6.5	9.1	11.9

Horizon and locality.—Chepultepec formation, 1.5 miles southwest of Mt. Clifton, Edinburg quadrangle, Va.

Discussion.—This species is characterized by the sub-rounded outline, length-width relationship, and produced cardinal extremities. In the latter respect, it is most similar to *F. auriculata*, but differs in size and overall outline. *F. logani* also resembles *F. buttsi*, but the greatly increased size of *F. buttsi* and the well-developed ventral valve wing points provide major differences.

Types.—Holotype USNM 126844a figured paratypes USNM 126844b–d.

FINKELNBURGIA ROANOKENSIS, n. sp.

Pl. 124, B, fig. 8–13

Description.—Shell moderately large for the genus, wider than long with greatest width about the middle; cardinal extremities acutely pointed; anterior margin broadly rounded, lateral margins convex anteriorly but gently concave just anterior to cardinal extremities; surface ornamentation multicostellate, smaller costellae predominant numerically, larger costellae unequal in spacing and development. Coarse growth lines present on some specimens.

Ventral valve moderately convex in lateral profile, with greatest inflation in mid-region; anterior porfile more regularly convex, posterolateral slopes to cardinal extremities straight to gently concave; interarea prominent in adults and gently to moderately steep. Cardinal extremities forming small ears in most adult specimens.

Dorsal valve medially marked by a sulcus orginating at the umbo and extending to the front margin, shallow and poorly defined in all specimens. Shells gently and regularly

convex in lateral and anterior profiles, indented at the summit in anterior profile; slopes to cardinal extremities slightly concave. In adult forms, cardinal extremities drawn out to small wing points.

Interior: Ventral valve with broad, sessile spondylium and short, stout median septum. Brachial valve with small, elongate, moderately elevated adductor platforms. Pallial trunks not deeply impressed in either valve.

Measurements in mm.:

	length	mid-width	hinge width
Holotype (brachial valve)	9.1	11.7+	10.3
Paratype (pedicle valve 126843c)	8.6	9.8	9.7
Paratype (pedicle valve 126843j)	9.5	11.8	10.3

Horizon and locality.—Chepultepec formation in an abandoned quarry on the east side of Carvin Creek, 0.6 mile N. 64° W. of the confluence of Carvin and Tinker Creeks, Roanoke quadrangle, Virginia.

Discussion.—This species is known only from the one locality, where it is abundant in several beds. These beds have also yielded silicified gastropods and breviconic cephalopods, along with non-silicified hystricurid trilobites.

F. roanokensis is closest to *F. bellatula* in specific characteristics. Greatest points of distinction are the straighter hinge line, a more subquadrate dorsal valve, and the more pronounced multicostation of *F. roanokensis*. Overall outline and size distinguish this form from *F. logani* and *F. buttsi*.

Types.—Holotype USNM 126843h; figured paratypes USNM .,126843a–c, e, i; measured paratype USNM 126843j; unfigured paratypes USNM 126843d, f, g, k.

FINKELNBURGIA BUTTSI Ulrich & Cooper, 1936

Pl. 124, C, fig. 14–20

Finkelnburgia buttsi ULRICH & COOPER, 1936, Jour. Paleont., vol. 10, p. 623. ——, 1938, Geol. Soc. Am. Special Paper 13, p. 135,136, pl. 24, fig. 12–25.

Description.—Shell somewhat large for the genus, wider than long; cardinal extremities acutely pointed in the young, less so in adults; lateral margins nearly straight or slightly convex; front margin broadly rounded; lateral profile subequally biconvex; surface multicostellate; costellae unequal and variable; strong concentric growth lines and varices of growth produce a beatiful cancellation.

Ventral valve gently convex in profiles, full in the middle and front but gently sulcate at the sides of the umbo; beak pointed and moderately elongated. The lateral slopes are gently concave. The cardinal extremities form small ears in most specimens.

The dorsal valve is strongly convex in lateral profile, but in anterior view it is flatly convex in the mid-region and gently convex on the lateral slopes. A sulcus, originating near the front of the umbo and extending to the front margin, is deepest at the front of the shell but narrow and shallow in all the specimens. The umbo is full and the beak incurved but inconspicuous. The portions of the shell bordering the sulcus and extending across the slopes to the anterolateral margins are full and convex, but the slopes to the cardinal extremities are gently concave. Inside the ventral valve the spondylium is short and firmly cemented on a short and thick septum.

Measurements in mm.:

	length	width	hinge width
Ventral valves			
91380h	7.0	9.0	12.0
91380k	9.0	14.0	14.5
Dorsal valves			
91380g	6.0	8.5	8.5
91380e	6.0	8.0	9.0

Holotype.—USNM 91380h; paratypes USNM 91380a–g, i–l; figured paratype, USNM 91380e.

Horizon and locality.—Chepultepec formation, 2.1 miles northwest of Quicksburg, Mt. Jackson quadrangle, Va., and 2.35 miles northeast of Fishersville, Waynesboro quadrangle, Va.

Discussion.—This larger species of the genus is known only from the localities cited. Near Quicksburg, it is abundant in a silicified condition in limestone with *Tentralobula delicatula*, permitting recovery of perfect valves of both. In its strongly angular, often mucronate hinge extremities and beautiful sculpture, *Finkelnburgia buttsi* is quite unlike any other species known

except *F. canadensis*, *F. logani*, and *F. virginica*. Compared with these it is perhaps most like the latter but differs in its more delicate and elaborate ornamentation and also in the outline and profiles of the valves. It is much shorter and narrower than *F. logani*.

Genus SYNTROPHINA Ulrich, 1928
SYNTROPHINA CAMPBELLI (Walcott)
Pl. 124, D, fig. 21–32

Syntrophina campbelli WALCOTT, 1908, Smithson. Misc. Coll., vol. 53, p. 107, 108, pl. 10, fig. 9,9a–c. ——, 1912, U.S. Geol. Survey, Mon. 51, p. 108, fig. 73.

Description.—Shell small, a little wider than long, subequally biconvex; hinge narrow, its width equalling or slightly less than half the greatest width; surface ornamented by concentric lines of growth only.

Ventral valve roundly elliptical in outline, evenly and gently convex in profile. In anterior view the median portion of the profile is slightly sulcate and the sides gently convex. Sulcus moderately deep and wide, defined in the front half; tongue slightly elongated, rounded; lateral lobes bounding the sulcus strongly convex; lateral slopes steep, faintly concave; beak low, interarea curved, apsacline.

Dorsal valve evenly but flatly convex in lateral profile, trilobate in anterior profile; fold low, visible about half the length of the valve, sharply rounded to subangular and bounded by shallow sulci; lateral slopes moderately convex, a little depressed below the fold in lateral profile; umbo gently convex, beak incurved, inconspicuous.

Interior: Septum strong, extending to the middle of the valve or beyond; spondylium small, brachiophore plates short, slightly divergent.

Measurements in mm.:

	length	width	hinge width
Ventral valves			
91614a	7.0	9.0	5.0
91612a	7.5	9.0	
Dorsal valves			
91614h	7.0	10.0	4.0
52480b	7.5	10.0	

Holotype.—USNM 52480 f; paratypes USNM 52480a–e; hypotypes USNM 91614a, b, d–g, i, j.

Horizon and locality.—Chepultepec limestone, Bunker Hill, 6 miles northeast of Rogersville, Tennessee; 1.8 miles northwest of Tazewell, Tennessee; Gasconade formation above and a short distance north of Pine Hollow Spring, Sec. 36, T. 28 N., R. 5 W., Eminence quadrangle, Missouri; on the road from Birch Tree to Winona, Missouri; Ellenburger limestone, 8.4 miles north of Cherokee on the San Saba road, Texas. Also found 0.3 mile east of Bolton, Russell Co., Va., in chert (residual) mixed with *Lecanospira* and *Hystricurus conicus* (Billings). (Butts, 1940)

Discussion.—This species resembles the middle Canadian *Syntrophina missouriensis* most closely. It differs in having a rounder contour, valves a little more inflated, gentler sulcus, and a more prominent fold which extends about to the middle of the valve. This species has been widely cited as characteristic of the Roubidoux formation in Missouri, but actually it is confined there to the upper part of the underlying Gasconade formation.

Genus TETRALOBULA Ulrich & Cooper, 1936
TETRALOBULA DELICATULA Ulrich & Cooper, 1936
Pl. 124, E, fig. 33–38

Tetralobula delicatula ULRICH & COOPER, 1936, Jour. Paleont., vol. 10, p. 628. ——, 1938, Geol. Soc. Am., Special Paper 13, p. 205, pl. 43, fig. 1–16.

Description.—Shell small, wider than long; subelliptical in outline; hinge narrow, equal to about three-fourths the width of the valve; lateral profile subequally biconvex; cardinal extremities rounded; anterior commissure uniplicate; surface very finely multicostellate.

Ventral exterior: Lateral margins gently rounded; anterior margin truncate; tongue bent at nearly right angles to the plane of the commissure; lateral and anterior profiles very gently convex; umbonal region full or a little swollen; sulcus originating abruptly at the middle of the valve, widening rapidly; lateral areas gently concave; beak obtusely pointed; interarea moderately long, apsacline.

Dorsal exterior: More transverse in outline than the ventral valve; lateral margins

strongly convex; lateral profile flatly convex; anterior profile gently arched; fold originating at the middle of the valve gentle, defined by shallow sulci; umbo flatly convex; lateral areas gently convex.

Ventral interior: Pallial trunks deeply impressed, narrowly divergent; spondylium equal in length to about one-third the length of the valve, sessile at the rear of the shell but elevated on a low septum at its front; margin of spondylium narrowly rounded in front; teeth short and small.

Dorsal interior: Platforms of adductor muscular attachment strongly developed, even in small shells; other features as described for the genus.

Measurements in mm.:

	length	width	hinge width
Ventral valves			
91904e	7.5	9.5	6.5
91904a	8.0	11.0	7.5
91904c	6.0	8.5	6.0
Dorsal valves			
91904j	6.0	8.0	
91904i	6.0	10.0	
91904g	4.5	8.0	

Syntypes—USNM 91904b, f, g, i, j.

Horizon and locality.—Chepultepec formation, 2.1 miles northwest of Quicksburg, Mt. Jackson quadrangle, Va.

Discussion.—This interesting species suggests *Tetralobula texana* but has a lower, shorter fold and a shorter tongue on the ventral valve.

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MANUSCRIPT RECEIVED APRIL 9, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1170–1172, PL. 125, SEPTEMBER 1956

A NEW DEVONIAN SPINOSE PLATYCERATID GASTROPOD[1]

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ABSTRACT—A new species of platyceratid gastropod, *Platyceras bartlettense*, is described from the Middle Devonian of Ontario. The species is characterized by exceedingly long, tapering spines which are sealed after their construction. No apparent morphologic use can be attributed to the spines at this time. It is hoped that this paper will stimulate study of spinose platyceratids.

A COLLECTION of well preserved crinoids obtained from shales of Middle Devonian age near Arkona, Ontario, has yielded several specimens of platyceratid gastropods attached to the calyxes. While this is not an unusual occurrence, the gastropods are unusual in the Paleozoic in exhibiting spines as much as 2 inches long, or more than twice the width of the body whorl bearing them. Rapid, undisturbed burial in a fine-grained matrix may be the reason for this remarkable preservation.

Spine-bearing platyceratids have been known from North America for more than a century (Conrad, 1840). More than a dozen species have been named from this continent. Most have been described from Devonian strata, although a few are known from beds of Mississippian age. Dr. J. Brookes Knight has called the writers' attention to *Platyceras spinigerum* Worthen, a spinose platyceratid, from the Pennsylvanian of Illinois. No spine-bearing platyceratids are known from the Permian.

Examination of American spinose species suggests that several different lines of the Platyceratidae independently developed spines. Naming of new genera, if any, should be delayed until more is known of the species. The group as a whole has been virtually neglected for more than 50 years. The specimens from Arkona are described in the hope of stimulating further study of this family.

A few of the better preserved spines on the specimens from Arkona, Ontario, show a suture line on the anterior side. This line marks the juncture of two curved half cylinders, demonstrating that the hollow spines were deposited by a portion of the mantle projecting upward through an original slight fold in the apertural margin and subsequently fused. The spines thus are formed similarly to those of productid brachiopods, and mollusks, particularly the Recent gastropods *Murex tenuispina* Lamark and *Guildfordia yoca* Jousseaume. Spines of all these forms taper gradually, so that there is only a tiny opening, if any, at the distal end.

In the Arkona specimens the base of the spines was sealed by a calcareous layer deposited on the interior of the shell after spine formations. All spine bases, including those just posterior to the margin, are sealed. Silicified specimens of *Platyceras dumosum* Conrad and *P. indianense* Miller & Gurley in the U. S. National Museum collection, from the Falls of the Ohio River (Pl. 125, fig. 7,8) also show all spine bases covered by the inner shell layer. Meek (1873, p. 211), remarked on the sealing off of spine bases, but this has been ignored by other workers. Closing of spines shortly after completion of growth probably is characteristic of all spiny platyceratids.

This sealing of the spine bases, especially those at the margin, proves conclusively that the spines could not be used as inhalent siphons, analogous to the tremata of *Haliotis*. Taylor (1954, p. 1111) has suggested reduction in the length and sharpness of spines on specimens of *Murex tribulus* from the Great Bitter Lake of Egypt, compared with specimens from the Red Sea, might be a reflection of the absence of voracious enemies in this specialized environment. Conceivably, the spines of the Devonian platyceratid could have had a protective function, but the gastropod enclosed within the arms of a crinoid was already partly protected.

[1] Publication authorized by the Director, U. S. Geological Survey.
[2] Formerly, U. S. Geological Survey.

The available evidence is not sufficient to determine whether or not the spines had any vital function.

The tips of some of the spines and the body whorl of several gastropods from the Arkona locality form the substrate for encrusting fistuliporoid bryozoans. The bryozoans apparently grew on the shell during its life, as the excellent preservation of the crinoids suggest that they and the attached platyceratids lay on the bottom for a relatively short time before being entombed in the mud. Some of the spines that have their ends encrusted with bryozoans are much shorter and blunter than others, suggesting the spines were broken during the life of the gastropod.

Class GASTROPODA
Order ARCHAEOGASTROPODA
Family PLATYCERATIDAE
Genus PLATYCERAS Conrad

PLATYCERAS BARTLETTENSE, n. sp.
Pl. 125, fig. 1–6

Platyceras dumosum rarispinum Hall. BOWSHER, 1955, pl. 2, fig. 1a-1c; pl. 2, fig. 9a-9c.

Description.—Naticiform gastropods with elongate spines commonly more than twice the width of the body whorl and arranged in two or three spiral rows; shell relatively regular, not uncoiling in mature stage; apertural margin with several distinct salients and reentrants conforming to irregularities of the echinoderm shell; straight, elongate spines, produced at nearly uniform intervals on the body whorl, these spines being arranged in two spiral rows, above and near the periphery, with a third row starting in the mature stage well below the periphery; ornamented by only growth lines.

Discussion.—This species is similar to *Platyceras dumosum rarispinum* Hall but differs in being smaller. *Platyceras bartlettense* differs from *P. parvispinum* Howell by being less compressed and bearing more spines. Hall (1859, p. 233) noted spines up to two inches long on *P. dumosum rarispinum* and figured a specimen with spines over an inch long (Hall 1879, pl. 28, fig. 20) but most subsequent workers have not commented on the length of spines, or have dealt with specimens preserving spine bases only.

The sedentary habit of platyceratid gastropods on echinoderms (Bowsher, 1955, p. 466) has resulted in much individual variation. It is possible, even highly probable, that when larger populations of earlier named species are investigated, *P. bartlettense* may prove to be a subjective synonym of one of these species. In the absence of large collections, no attempt is made here to pass on the zoologic validity of the several species. Except for this new species, the echinoderm hosts of the several spine bearing platyceratid species seemingly are unknown.

Platyceras arkonense was named by Shimer & Grabau (1902, p. 178) from Bed E at river level at Bartlett's Mill near Arkona, Ontario. It is thus from the same stratigraphic level and geographic locality as *P. bartlettense*. The description indicates that *P. arkonense* bore spines, but most other details are lacking, as the long description is devoted mostly to discussion of phylogenesis. The species is not illustrated and there is no indication where types are deposited. They apparently are not in the collections of the American Museum of Natural History or the Massachusetts Institute of Technology. Under the circumstances it seems better to name a new species rather than use the earlier name.

The specimens of *P. bartlettense* illustrated are attached to the tegmen of *Arthroacantha carpenteri* (Hinde), identified by Dr. Edwin Kirk. Hinde (1885, p. 172) noted that three platyceratid gastropods on specimens of *A. carpenteri* had

> . . . very definite position in relation to the anal aperture of the crinoid, so far as it can be determined by the situation of the anal plate; and they are placed that the front margin of the gastropod shell would just project over this aperture.

With such an orientation, the marginal spines would project almost horizontally between the arms of the crinoid and probably would not have interfered with their function.

Holotype.—USNM 125693.

Figured specimens.—USNM 125694a–d.

Horizon and locality.—Arkona beds of Grabau (1917, p. 341), 26 feet below the base of the Hungry Hollow formation of Cooper & Warthin (1941, p. 260), Hamilton group, Middle Devonian. In bluffs, one foot

above level of Aux Sables River, Hungry Hollow (also known as Bartlett's, Marsh's or Marshall's Mill), 2 miles east of Arkona, West William township, Middlesex county, Ontario.

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MANUSCRIPT RECEIVED MARCH 5, 1956.

DESCRIPTION OF PLATE 125

All figures except 4 natural size

FIG. *1–6*—*Platyceras bartlettense,* n. sp. All specimens from Arkona, Ontario. *1,* Paratype in approximate position of life on *Arthroacantha carpenteri* (Hinde). Incrustations on body whorl are fistuliporoid bryozoans. USNM 125694a. *2,* Oblique apical view of paratype showing three spines, the middle one having its tip covered by a bryozoan colony. USNM 125694b. *3,* Side view of another paratype showing four spines. The two left spines and three others not seen form one row. The two right spines with bases removed form a second row. USNM 125694c. *4,* Enlargement of spine base shown in fig. 3 showing growth lines and sutures; X3. *5,* Paratype showing alignment of spines in a revolving row. Note short broken spine near specimens aligned with crinoid columnal. USNM 124694d. *6,* Holotype showing a long tapering spine on right side of slab. USNM 125693.

7–8—*Platyceras indianense* Miller & Gurley. *7,* Exterior view of hypotype from falls of the Ohio River. The semicircular emargination probably surrounded a spike on the crinoid calyx. *8,* Interior view of same specimen showing sealing of base of all spines, including one at the aperture. USNM 99458a.

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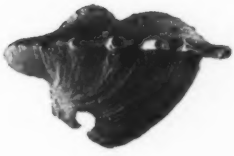

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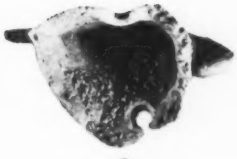

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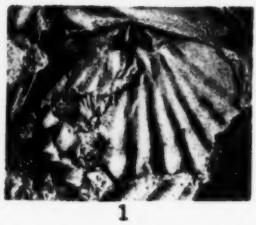
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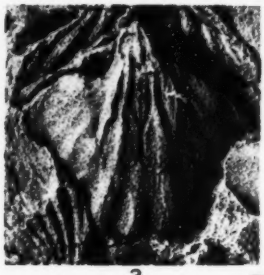
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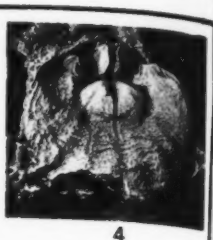
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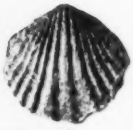
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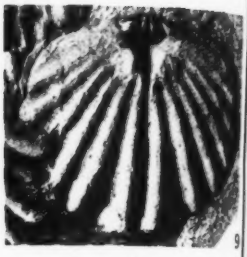
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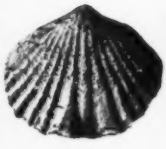
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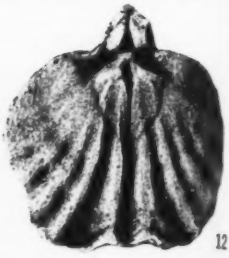
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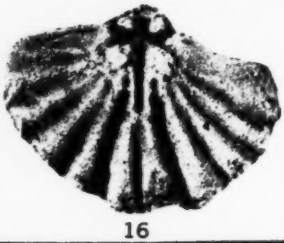
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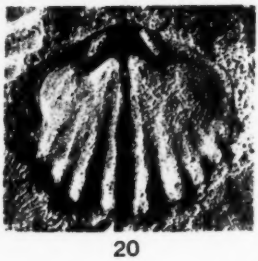
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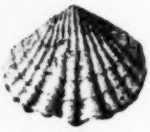
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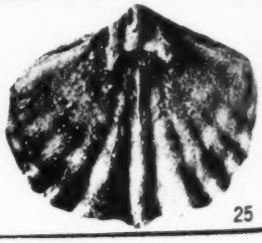
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JOURNAL OF PALEONTOLOGY, VOL. 5, P. 1173–1178, PL. 126, 1 TEXT-FIG., SEPTEMBER 1956

AUSTRALOCOELIA, A NEW LOWER DEVONIAN BRACHIOPOD FROM SOUTH AFRICA, SOUTH AMERICA, AND AUSTRALIA

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ABSTRACT—Specimens formerly assigned to *Leptocoelia flabellites*, from the Lower Devonian of South America and South Africa, are described and assigned to *Australocoelia tourteloti*, n. gen., n. sp. *"Leptocoelia" polyspera* from the Lower Devonian of Tasmania, Australia, also belongs to the new genus. The new genus is grouped with the exclusively North American genus *Leptocoelia* in the new family Leptocoeliidae.

INTRODUCTION

F. R. C. Reed (1925, p. 216, 217) discussed the austral Devonian faunas and concluded that assemblages from the Lower Devonian of South Africa and South America have much in common, but that they do not closely resemble either the Lower or the Middle Devonian faunas of western Europe. Reed thought that these austral faunas were, however, more closely related to the Lower Devonian faunas of eastern North America. The new genus *Australocoelia*, specimens of which were formerly considered by other workers to be *Leptocoelia flabellites*, serves further to reinforce Reed's conclusions, as it

[1] Publication authorized by the Director, U. S. Geological Survey.

EXPLANATION OF PLATE 126

Australocoelia tourteloti, n. gen., n. sp.

FIG. *1,2*—Internal impressions of brachial and pedicle valves, ×2. *1*, NYSM 8274; *2*, on same specimen as NYSM 8274. Bokkeveld beds. Ceres, Cape Colony, South Africa.

3,4—Internal impressions of pedicle and brachial valves, ×2. *3*, NYSM 10790; *4*, NYSM 10797, on same specimen as fig. 3. Port Louis, East Falkland. Devonian.

5—Internal impression of brachial valve, ×2, NYSM 10791. Port Salvador, West Falkland. Devonian.

6–8,12—Respectively one exterior brachial view, two exterior pedicle views and internal impression of pedicle valve. *6*, NYSM 10793, ×1; *7*, NYSM 10795, ×1; *8*, NYSM 10794, ×1; *12*, NYSM 10796, ×2. 6–8, Lomas de los Piojos; 12, Quebrada de Talacaste, San Juan, Argentina. Devonian.

9—Internal impression of brachial valve, ×2, NYSM 10792. Ponta Grossa, Paraná, Brazil. Devonian.

10—Holotype, internal impression of brachial valve, ×2, USNM 125134. USGS loc. 3135-SD, Comorapa-Tunal region, Department Santa Cruz, Bolivia. Lower Devonian.

11,13—Brachial interior (latex cast) and internal impression of pedicle valve, ×2, USNM 125135. Age and locality same as for fig. 10.

Australocoelia polyspera (Gill)

FIG. *14,15*—Impressions of pedicle and brachial interiors, ×3, respectively Nat. Mus. Victoria P-16810 and P-16811. Bell Shale, Right bank of Little Henty River, western Tasmania.

Australocoelia? aymara (Salter)

FIG. *16,17*—Impressions of brachial and pedicle interiors (plaster casts), ×2, USNM 125133; respectively British Mus. Nat. Hist. specimens B.M. (B. 81459) and B.M. (B. 81456). Side of Huaina Potosi, Bolivia. Lower Devonian.

Australocoelia palmata (Morris & Sharpe)

FIG. *18*—Brachial interior (latex cast), ×1, USNM 125131; figured Morris & Sharpe, 1846, Geol. Soc. London, Quart. Jour., vol. 2, pl. 10, fig. 3. Falkland Islands. Lower Devonian.

19—Pedicle interior (latex cast), ×1, USNM 125132; figured Morris & Sharpe, 1846, pl. 10, fig. 3c. Falkland Islands. Lower Devonian.

Leptocoelia flabellites (Conrad)

FIG. *20,21*—Impressions of brachial and pedicle interiors, ×2; USNM Acc. No. 120092, USNM No. 125136. Gaspé sandstone, 3/4 mile west of Gaspé village, Quebec.

22–25—Specimens from Glenerie limestone of Chadwick (1908); on New York route 9 W, 1 mile north of Glenerie, 1 mile south of Cockburn, New York. USNM Acc. No. 167820, USNM No. 125138. *22,23*, exterior and interior of pedicle valve, ×1; *24,25*, exterior and interior of brachial valve, ×1 and ×2.

is closely related to a North American genus.

The term "Flabellites Land," introduced by Clarke (1913) and recently discussed by Reed (1949, p. 125) perforce becomes a misnomer, as the species *Leptocoelia flabellites* is not now known to occur in the austral province. If the concept is a useful one the term should be revised.

The geographic range of *Leptocoelia* s.s. is restricted to North America, from the Llano uplift (Cloud & Barnes, 1946, p. 118, pl. 44, fig. 1–6) of Texas and the Eureka District of Nevada (*"Trematospira" infrequens* Walcott, 1884, Merriam, 1940, p. 54) to the Gaspé region of Quebec (Pl. 126, fig. 20–21).

The writers of this paper independently came to the conclusion that the genus here described as *Australocoelia* was new. Boucot based his conclusions on Bolivian material, and Gill on Tasmanian material. Subsequently Dr. G. A. Cooper of the U. S. National Museum with whom both Boucot and Gill were in contact brought to their attention his suggestion that they might both be contemplating the erection of the same genus. After correspondence and interchange of specimens and photographs had confirmed Dr. Cooper's suspicions, the writers collaborated in the preparation of this paper.

Phylum BRACHIOPODA
Superfamily ATRYPACAEA
Family LEPTOCOELIIDAE, n. fam.

Definition.—Coarsely and angularly plicate atrypoids having well developed fold and sulcus, and mound-like cardinal process surmounted by one or more linear ridges. Family is considered to include the genera *Leptocoelia* and *Australocoelia*.

Genus AUSTRALOCOELIA, n. gen.
Pl. 126, fig. 1–15,18,19

Type species: *Australocoelia tourteloti*, n. sp.

Diagnosis.—*Australocoelia* has a mound-like cardinal process (Pl. 126, fig. 11) surmounted by a median linear ridge whose upper face is swollen and bulbous. In large specimens this bulbous termination of the median linear ridge may be terminally bifid. The pedicle callist is deeply impressed (Pl. 126, fig. 13). In addition the pedicle muscle field of *Australocoelia* is relatively narrow (Pl. 126, fig. 13). The hinge teeth have a laterally elongate posterior face, and are triangular in cross section; the apex of the triangle pointing anteriorly.

Description.—Exterior: Unequally biconvex pedicle valve having the greater convexity, flanks, angularly plicated, pedicle beak suberect. Hinge line short, curved anteriorly. Anterior commissure sulcate.

Brachial interior: Mound-like notothyrial platform surmounted by blade-like median ridge that is terminally swollen. Adductor impressions anterior of the notothyrial platform.

Pedicle interior: Stout hinge teeth, triangular in cross section, apex of triangle directed anteriorly. Paired, striate adductor impressions anterior of deeply impressed pedicle callist.

Comparison.—*Australocoelia* is characterized by the distinctive nature of its cardinal process, pedicle callist, and hinge teeth as compared with the externally homeomorphous genus *Leptocoelia*. The nature of the cardinal process was mentioned by Clark (1913, p. 272, 273) but no taxonomic significance was attached to it. The bulbous termination of the median ridge is unlike that of *Leptocoelia* (Pl. 126, fig. 25) which has only a simple blade-like median ridge terminally unmodified. The hinge teeth of *Australocoelia* are triangular in cross section whereas those of *Leptocoelia* are elliptical in cross section. The beak of *Australocoelia* is suberect, that of *Leptocoelia* incurved.

Topotype specimens of *Leptocoelia flabellites* have not been figured in this paper because of the relatively poor quality of specimens available from the Oriskany sandstone as contrasted with the well preserved, figured specimens from the Glenerie limestone (Chadwick, 1908) and the Gaspé sandstone. Comparison of the Glenerie and Gaspé specimens with ones from the Oriskany leave no serious question as to their specific identity.

Australocoelia is represented in most collections by casts and molds. The linear base of the cardinal process is represented on these impressions by a slit (Pl. 126, fig. 1,4,9,10,12,15) whereas in *Leptocoelia* the more massive base is represented by a circular depression (Pl. 126, fig. 20). The differing configurations of the notothyrial platform are very noticeable in the figures cited.

Remarks.—The northernmost occurrence of *Australocoelia*, known to us, is represented by material in the U. S. National Museum (USNM 125137) said to have been collected "Between Saman and Pirin, 6 miles North of the North end of Lake Titicaca, Peru," by F. L. Wilde from "Devonian black shale east flank of hills."

It is possible that Salter's "*Orthis aymara*" is synonymous with *Australocoelia tourteloti*, but H. M. Muir-Wood (communication, 1955) writes as follows regarding Salter's types:

> I have looked for the original specimens of *Orthis aymara* from Bolivia mentioned in your letter of 16th March. We have a number of specimens in the Forbes collection which are said to come from Bolivia and one very poor object has a label referring it to Salter's paper published in the Q.J.G.S., vol. 17, 1861, p. 68, pl. iv, fig. 14. The specimen on the block does not resemble the figure at all closely, and is much smaller, and only partly preserved.

Therefore, owing to the unlikelihood of establishing the identity of Salter's material (Pl. 126, fig 16,17) at this time it is advisable to set up a new species based on more adequate material.

Examination of replicas of the types of *Atrypa palmata* Morris & Sharpe, provided by H. M. Muir-Wood (Pl. 126, fig. 18,19), leaves no doubt that they belong to *Australocoelia* but their specific relations with *A. tourteloti* could not be determined. Since it is unlikely that the specific identity of their material can be determined at this time, it is inadvisable to base a new genus on it.

Terebratula peruviana d'Orbigny may belong to *Australocoelia* but in the absence of adequate comparative material this could not be determined from figures alone.

Geologic range.—Lower Devonian, and possibly Middle Devonian (Kozlowski, 1923, p. 96).

Geographic range.—Brazil, Bolivia, Peru, Uruguay, Argentina, Falkland Islands, South Africa, Tasmania.

Species assigned.—From South America, South Africa, Falkland Islands, and Australia:

Australocoelia tourteloti, n. sp. (Bolivia)

Orthis palmata Sharpe, 1856, Geol. Soc. London, Trans., vol. 7, p. 207, pl. 26, fig. 6–10. (Falkland Islands)

Atrypa palmata Morris & Sharpe, 1846, Geol. Soc. London, Quart. Jour., vol. 2, p. 276, pl. 10, fig. 3. (Falkland Islands)

Leptocoelia polyspera Gill, 1950, Roy. Soc. Tasmania, Papers & Proc. for 1949, p. 245–46, pl. 1, fig. 25–28,38 (Australia)

Species assigned questionably.—From South America and the Falkland Islands:

Terebratula peruviana d'Orbigny, 1842, Voyage à l'Amerique Méridionale; Paléontologie, vol. 3, pt. 4, p. 3b, pl. 2, fig. 22–25. [The illustrations strongly suggest *Australocoelia*.]

Orthis aymara Salter, 1861, Geol. Soc. London, Quart Jour. 1861, vol. 17, p. 68, pl. 4, fig. 14.

AUSTRALOCOELIA TOURTELOTI, n. sp.
Pl. 126, fig. 1–13

Leptocoelia flabellites ULRICH, 1893 (not Conrad), Versteinerungen aus Bolivien, Neues Jahrbuch, Beil.-Band. 8, p. 60–64, pl. 4, fig. 9–13. (Bolivia).

Vitulina pustulosa KAYSER, 1897 (not Conrad), Beiträge zur Kenntniss einiger paleozoischer Faunen Süd-Amerikas, Deutschen geol. Gesell., Zeitschrift, Bd. 49, p. 296, pl. 9, fig. 6–7,9–10. (Argentina).

Leptocoelia flabellites CLARKE, 1913, (not Conrad), Fosseis Devonianos do Paraná, p. 269–275, pl. 22, fig. 13–24,27–32. (Brazil and South Africa).

Leptocoelia flabellites KOZLOWSKI, 1913 (not Conrad), Fossiles Devoniens de l'État de Parana (Brésil), Annales de Paléontologie, Tome 8, Fascicule 3,4, p. 9–10, pl. 2, fig. 1–2. (Brazil).

Leptocoelia flabellites MENDEZ-ALZOLA, 1938 (not Conrad), Fosiles Devonicos del Uruguay, Boletin del Instituto Geologico del Uruguay, Bol. no. 24, p. 28–29, pl. 7, fig. 4–10. (Uruguay).

Description.—Exterior: Unequally biconvex, pedicle valve having greater convexity. Five or six angular plications on each flank, plus additional plication in pedicle valve sulcus and corresponding pair on brachial fold. Outline of valves subcircular, greatest width at midlength. Pedicle beak suberect (anacline). Fold on brachial valve bearing median groove. Hinge line short, curved in anterior direction, corresponding to submegathyrid condition in terebratuloids.

Brachial interior: Cardinalia consisting of mound-like cardinal process surmounted by median ridge which is terminally swollen. Crural plates lateral of cardinal process in large shells, projecting up and paralleling cardinalia while forming frontal margins of partly denticulate dental sockets. Anterior of cardinalia is low median septum extending anteriorly almost two thirds length of shell. Base of cardinal process fused to adjacent

crural plates by secondary material; in small shells these structures are distinct. Two pairs adductor muscle scars anterior of notothyrial platform, extending anteriorly one-third length of shell. Anterior margin crenulated by impress of external ornamentation.

Pedicle interior: Stout hinge teeth, triangular in cross section with apex directed anteriorly, lie on either side of delthyrial cavity. Paired, striate adductor impressions lie anterior of deeply impressed pedicle callist. Anterior margin crenulated by impress of external ornamentation.

The holotype (USGS locality No. 3135-SD, USNM No. 125134) is from the Comorapa-Tunal region, Department of Santa Cruz, Bolivia; collected by H. Tourtelot and Rodriguez in 1953 (their locality No. T53B-38) and is cited by them as follows:

> fossils were found in float . . . stream bottom . . . may have come from anywhere in the section . . . . Section on north side of ridge between Comparapa and Tunal, and on the slope into the Rio Pulgnina. Comparapa is at Kilometer 254 on the Cochabamba-Santa Cruz highway. Tunal is about 10 km by horseback northeast of Comarapa.

The paratypes (USGS locality No. 3135-SD, USNM No. 125135 and USGS locality No. 3136-SD, USNM No. 125285) are from the above locality.

Geologic range.—Lower Devonian, and possibly Middle Devonian.

Distribution.—Brazil, Bolivia, Peru, Uruguay, Falkland Islands, Argentina, South Africa.

Remarks.—Associated with *A. tourteloti* in the collection from USGS locality No. 3135-SD is *Mutationella* sp., a metaplasiid of the *Metaplasia plicata* Weller, 1903, type, a coarsely plicated (6–8) spiriferoid that resembles both *Hysterolites* and *Howellella* externally, *Schuchertella* sp., *Chonostrophia?* sp.

The above assemblage has an Early Devonian aspect as evidenced by *Australocoelia* itself which is similar to *Leptocoelia*, a coarsely plicated spiriferoid similar to such forms as *Hysterolites primaevus* (Steininger, 1853), *Hysterolites murchisoni* (Castelnau, 1843) and *Howellella cyclopterus* (Hall, 1867), a metaplasiid which is similar to *M. plicata*, *Mutationella*, and a chonostrophiid similar to *Chonostrophia dawsoni* (Billings, 1874).

AUSTRALOCOELIA POLYSPERA (Gill)
Pl. 126, fig. 14,15

Leptocoelia polyspera GILL, 1950, Royal Soc. Tasmania, Papers & Proc. for 1949, p. 245–247, pl. 1, fig. 25–28,38.

Description.—Exterior: Unequally biconvex, pedicle valve having a marked convexity and brachial valve sub-planate except for rather sharp marginal flexure. About seven plications on each flank, plus additional plication in pedicle valve sulcus and corresponding pair on brachial fold. Outline of valves suboval; precise nature of outline difficult to determine because of distortion due to tectonic movement, but shell longer than wide and approximately of proportions seen in Pl. 126, fig. 15. Greatest width posterior to midlength. Fold on brachial valve bears median groove. Hinge line short, curved anteriorly from midline.

Brachial interior: Cardinalia consist of prominent mound-like cardinal process surrounded by median ridge which is wider anteriorly. Crural plate on each side of process, projecting up parallel to cardinalia while forming frontal margins of dental sockets. Anterior of cardinalia is low narrow median septum reaching a point about two thirds length of shell from posterior extremity. Base of cardinal process fused to contiguous crural plates by secondary material. Two pairs adductor muscle scars anterior of notothyrial platform, extending anteriorly about one third length of shell. Anterior margin crenulated by impress of plications which involve the whole thickness of the shell. Internal secondary deposition makes the plications less sharp on much of the interior surface.

Pedicle interior: Stout hinge teeth, subtriangular in cross section, lie on either side of the delthyrial cavity. Paired adductor impressions lie anterior of the deeply impressed pedicle callist. Fine median septum extends to a point about two thirds of the length of the valve from the posterior extremity.

Comparison.—*A. polyspera* differs from the type species of the genus, *A. tourteloti*, in size, outline, number of plications, and detail of internal structures.

Occurrence.—The holotype (P14795, National Museum of Victoria) was collected from light-grey siltstone on the right bank of the Little Henty River, Western Tasmania, Australia (see map, Gill & Banks

1950). The paratype (P14796–7) is from the same locality, as also are the hypotypes now presented (P16810–16811, Pl. 126, fig. 14, 15). In addition to the type locality, *A. polyspera* occurs at the following localities:

1. Trench, NE side of Silver Bell mine, near Zeehan, Tasmania.
2. Right (west) bank of Little Henty River, 2 to 3½ chains north of track running east to the river from the Silver Bell mine.

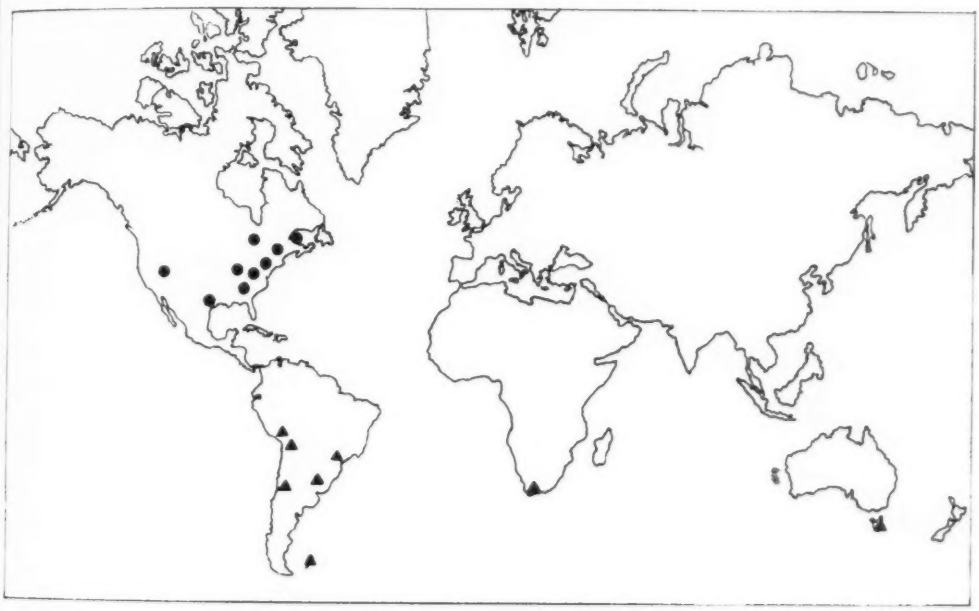
Strata exposed at the three known localities probably all belong to the same stratigraphic horizon. Search of collections from various parts of Australia, and of collections from the Baton River and Reefton Beds in New Zealand has failed to locate other occurrences of *A. polyspera*. As far as is known, this species occurs in Australasia only in the Zeehan district of Tasmania, and no other species of *Australocoelia* has been recognized. Its occurrence appears to be strictly controlled by facies, for it abounds in a particular siltstone but disappears immediately when there is a change in lithofacies.

Geologic range.—Bell shale, western Tasmania. Lower Devonian. Two formations of Lower Devonian age are known in western Tasmania, viz. Bell shale (younger) and Florence quartzite (older), and *A. polyspera* is known only from the younger formation. Still younger beds of Lower Devonian age are known further north in Victoria. Tentatively, the Bell shale may be regarded as middle Lower Devonian.

ZOOGEOGRAPHY

Text-fig. 1 presents the distribution of the Leptocoeliidae as at present known. *Leptocoelia* s.s. is limited to North America. *Australocoelia* is well represented in the austral (Malvinocaffric) paleobiological province, viz. South America and South Africa, but surprisingly enough appears also in Australia which Gill (1953) assigns to the Boreal province.

In 1935 Allan claimed to find a strong Austral element in the Lower Devonian



• Known distribution of *Leptocoelia*

▲ Known distribution of *Australocoelia*

Scale approximately 1:125,000,000

fauna of Reefton, New Zealand, and influenced by this, Du Toit (1937) suggested a Samfrau geosyncline connecting South America, South Africa, Antarctica and Australasia before (in his view) those continents drifted apart. In 1947 Allan revised the Reefton Brachiopoda and found then no relationship between the New Zealand and Austral faunas. Gill (1949, 1952) has shown the trilobite evidence likewise does not prove connection with the Austral province. *Australocoelia* appears to be the first definite connecting link between the Austral province and Australia. On present knowledge it is not possible to indicate the paleogeographic route by which this linkage came about, nor why this genus travelled the route and others did not. New evidence is becoming available to Gill that the Austral province suffered glaciation in the Lower Devonian, and it is possible that the distribution of *Australocoelia* is due to its having been a eurythermal form which could thrive in both the frigid climate of the Lower Devonian antarctic and the warmer coral-growing waters of the Boreal province.

The circum-antarctic distribution of *Australocoelia* is unique among Early Devonian brachiopods and suggests that distribution pathways were available in this region. The absence of leptocoeliids in Europe or Asia rules out the possibility that *Australocoelia* might have had a European or Asiatic origin. The related genus *Leptocoelia* occurs in North America but the age of the containing strata is approximately that of those from which *Australocoelia* was obtained, which makes it difficult to decide whether one genus gave rise to the other or whether both genera arose from a common ancestor. In any event, the evidence does suggest that communication of marine forms between North America and South America was possible at this time.

ACKNOWLEDGEMENTS

Dr. H. M. Muir-Wood generously provided replicas of *Orthis aymara* Salter and *Atrypa palmata* Morris & Sharp; without her aid the description of *Australocoelia* would have been greatly hampered.

Dr. Donald W. Fisher and Mr. Clinton Kilfoyle of the New York State Museum loaned material studied by John M. Clarke from the collections of that institution. Without Clarke's material this study would not have been feasible.

Dr. G. A. Cooper pointed out that "*Trematospira*" *infrequens* Walcott, 1884 was a leptocoeliid; subsequent preparation of the interior by one of us (A.J.B.) showing that this species belongs to *Leptocoelia* s.s.

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MANUSCRIPT RECEIVED MAY 31, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1179–1186, PL. 127, 128, SEPTEMBER 1956

JURASSIC MOLLUSCA FROM PERU

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ABSTRACT—The paper describes five species of Gastropoda (four new: *Ampullella peruviana, Cossmannea nascaensis, C. peruviana, Nerinella caballensis*) and nine of Pelecypoda (one new: *Cercomya peruviana*) collected by Dr. W. Rüegg at two localities near the coast in the Nasca area of Peru. It is concluded that the "Río Grande formation" (of Rüegg) from which they came is of Bajocian age, as previously suggested by fragmentary ammonites.

INTRODUCTION

THIS paper deals with a series of gastropods and pelecypods collected by Dr. W. Rüegg at two localities near the coast in the Nasca area of Peru (latitude about 15° S). Dr. Rüegg's account of the geology of the area is at present in course of publication in the Geologische Rundschau. One locality is situated 4 km. upstream from Santa Ana at the mouth of the Río Grande, and the other about 1.4 km. E by S of Puerto Caballa, 7 km. NW of Santa Ana. The fossiliferous rock at both localities is a pink calcareous deposit belonging to a predominantly volcanic series which Dr. Rüegg proposes to term the "Río Grande formation." This formation was included by Steinmann (1929, p. 81) in his "Andine Diabas-Melaphyrformation," which some previous workers had called the "Porphyritic Formation." Dr. Rüegg has kindly presented the fossils described to the Department of Geology of the British Museum (Natural History), the registration numbers cited being those of the Department in question.

GEOLOGICAL AGE OF THE FOSSILS DESCRIBED

The occurrence of a few fossils submitted to specialists in other groups had already led to the provisional conclusion that the fossiliferous deposits are of Bajocian or Bathonian age. Fragmentary ammonites from the Río Grande locality had been submitted to Dr. W. J. Arkell, who identified some as *Planammatoceras* aff. *P. planinsigne* (Vacek) and thought that others probably belonged to the same species as specimens from Chile which Möricke (1894, p. 16, pl. 4, fig. 11) had recorded as *Hammatoceras alleoni* Dum., and Jaworski (1926, p. 224) had considered referable to *H. semilunatum* Janensch. These determinations, which, however, needed confirmation by better material, suggested that the beds represent the *opalinum* or the *scissum* Zone of the lower Bajocian. Both localities yielded fossil corals determined by Dr. J. W. Wells as *Astrocoenia* aff. *A. hyatti* Wells, *A. hyatti* itself being a species from the Sundance formation of Wyoming, indicated by Imlay (1952) to be Callovian-Oxfordian in age. Corals from a third locality where the Río Grande formation is exposed (Tres Palos-Mal Paso, 33.5 km. NNE of Puerto Caballa) were identified as *Calamophyllia* aff. *C. radiata* (Lamouroux) and *Astrocoenia* cf. *A. hyatti* Wells, *C. radiata* being a species of the European Bathonian.

The gastropods and pelecypods here described have been identified as follows:

Gastropoda

Bathrotomaria sp.
Ampullella peruviana, n. sp.
Cossmannea nascaensis, n. sp.
Cossmannea peruviana, n. sp.
Nerinella caballensis, n. sp.

Pelecypoda

Entolium demissum (Phillips)
Lima (*Plagiostoma*) cf. *L.* (*P.*) *alticosta* Chapuis & Dewalque
Ctenostreon pectiniforme (Schlotheim)
Trigonia stelzneri Gottsche
Lucina cf. *L. bellona* d'Orbigny
Lucina goliath Gottsche
Pleuromya uniformis (J. Sowerby)
Cercomya undulata (J. de C. Sowerby)
Cercomya peruviana, n. sp.

This list includes only six forms which have been identified definitely with species described previously. Four of these (*Entolium demissum, Ctenostreon pectiniforme, Pleuromya uniformis*, and *Cercomya un-*

dulata) are species found also in Europe, where they have a long geological range, starting in the case of the *Entolium* in the Toarcian and in the other three cases in the Bajocian, and extending in all cases to the Oxfordian or higher. Their presence, therefore, merely shows that the beds are of Middle or Upper Jurassic age. The other two (*Trigonia stelzneri* and *Lucina goliath*) are species which have so far been recorded only from South America, where they appear to be characteristic of the Bajocian, a record of *T. stelzneri* from the Callovian being based, most probably, upon a misidentification.

Of the species described as new, two appear to be particularly close to forms known from North America. These are *Nerinella caballensis*, which is very similar to *N. maudensis* (Whiteaves), originally described from beds in British Columbia which probably belong to the Bajocian, and *Cercomya peruviana*, which is comparable, on the other hand, with a Callovian species, *C. punctata* Stanton. The most notable new species is *Ampullella peruviana*, which most closely resembles certain European species of uppermost Jurassic (Portlandian) age. It is thus clear that such resemblances between species of long-ranging genera afford evidence which is too conflicting to be of help in deciding upon the exact geological age of the formation. Qualified identifications, such as that of *Lima* (*Plagiostoma*) cf. *L.* (*P.*) *alticosta*, are also of little use for this purpose. The evidence of the gastropods and pelecypods as to the exact stage of the Jurassic represented by the Río Grande formation is thus somewhat meagre, but the presence of the two species *Trigonia stelzneri* and *Lucina goliath* supports the provisional conclusion from the fragmentary ammonites that the age is Bajocian.

The Río Grande formation may thus be added to the known occurrences of Bajocian-Bathonian rocks in Peru, of which those previously known (as summarized by Steinmann, 1929, p. 75–80) are as follows:

Hacienda de Chunumayo, Dep. Huancavelica. Liassic and Bajocian fossils described by Jaworski (1915); several species figured by Steinmann (1929).

Hacienda Yanauctuto, Hacienda Ila, and Santa Barbara, Dep. Huancavelica. A few Bajocian ammonites are reported by Jaworski (1914, p. 305, 312) and Steinmann from these localities.

Sumbay and Lagunillas, between Arequipa and Puno, in area west of Lake Titicaca. A few ill-preserved silicified fossils, including *Nerinea*, possibly of Bajocian-Bathonian age, are reported by Jaworski (1914, p. 305) and Douglas (1920, p. 29, 31) from these localities.

DESCRIPTION OF THE FOSSILS

Class GASTROPODA
Family PLEUROTOMARIIDAE
Genus BATHROTOMARIA Cox, 1956
BATHROTOMARIA sp.
Pl. 127, fig. 1

Material.—One broken specimen (G. 71533).

Description.—This specimen, which consists apparently of the earlier whorls which have been broken away from the rest of the shell, is conical in shape and about 34 mm. high and 30 mm. in diameter. There is no umbilicus. The whorls have an obtuse, rounded-off median angulation of about 150°, separating a steep, flattened ramp

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EXPLANATION OF PLATE 127

Illustrations are of natural size unless enlargement is stated. Localities are given in text. Registration numbers are those of the Geological Department of the British Museum (Natural History).

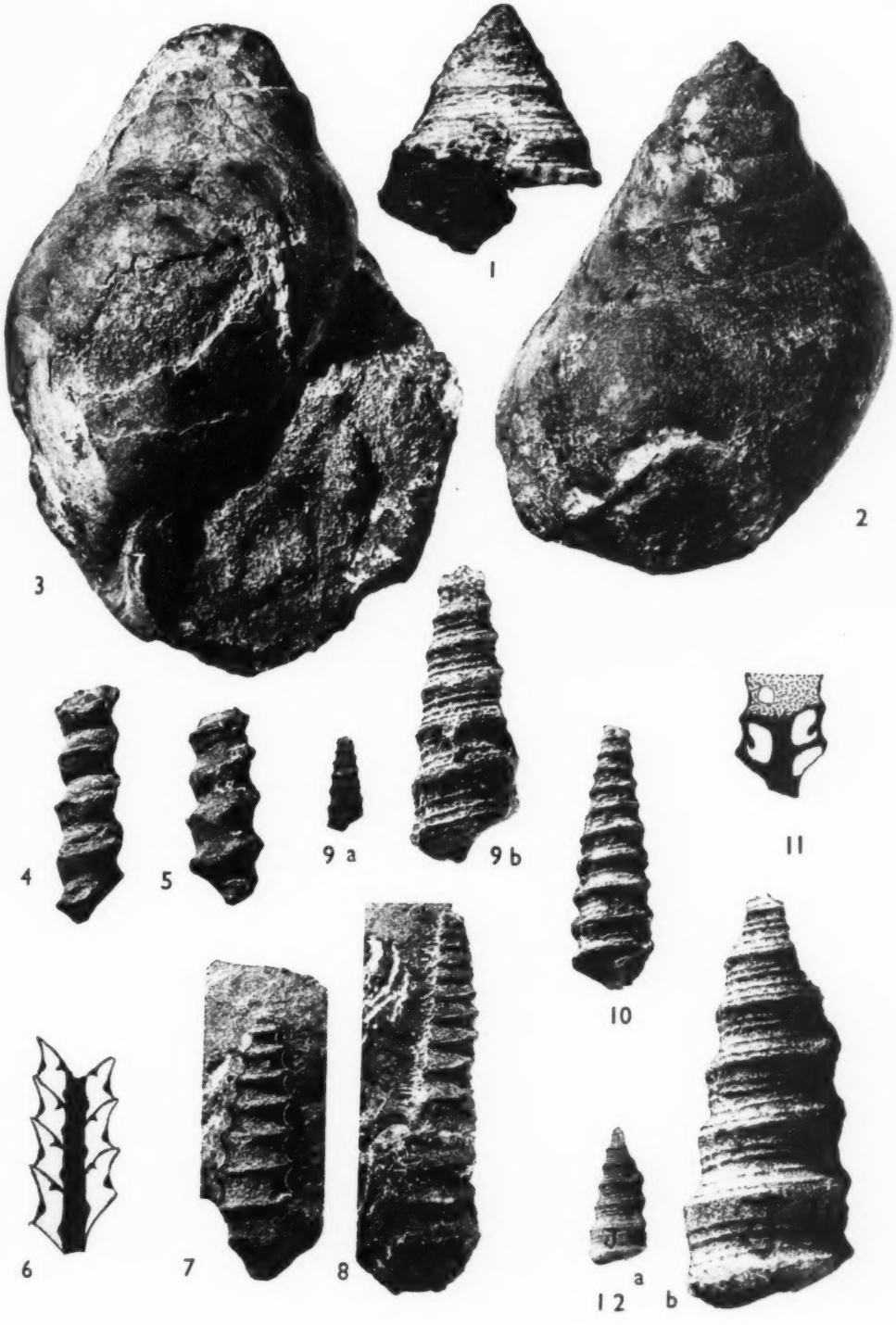
FIG. 1—*Bathrotomaria* sp. G.71533.

2,3—*Ampullella peruviana*, n. sp. *2*, Holotype G.71534; *3*, paratype, G.71535.

4–6—*Cossmannea nascaensis*, n. sp. *4*, Holotype, G.71543; *5,6*, paratypes, G.71544, G.71545, axial section of the last represented diagrammatically (×1.5).

7,8—*Cossmannea peruviana*, n. sp. *7*, Holotype, G.71515; *8*, paratype, G.71517.

9–12—*Nerinella caballensis*, n. sp. *9a,b*, paratype, G.71524 (*b*, ×3); *10*, paratype, G.71525 (×2); *11*, paratype, G,71526, axial section of later whorls (×2); *12a,b*, holotype G.71523 (*b*, ×3).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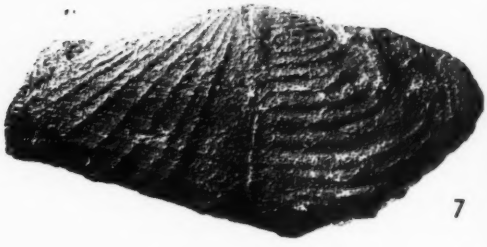

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from a very slightly concave side which is inclined slightly towards the axis in an adapical direction. The side bears three and the ramp two depressed, rounded, subequal cords. On the last preserved whorl the side is limited adapically by a rounded carina, forming the margin of the base. This carina is partly visible on the preceding whorl, bordering the suture. The selenizone evidently coincided with the median angulation of the whorls. The growth lines are not clearly visible owing to the eroded condition of the specimen.

This specimen is a typical representative of the genus *Bathrotomaria*, but appears to belong to a new species. In most of the comparable European Jurassic species, such as *B. textilis* (Eudes-Deslongchamps), of the Bajocian, there are more numerous and finer spiral threads.

Locality.—One km. E by S of Puerto Caballa.

Family AMPULLOSPIRIDAE
Genus AMPULLELLA Cox, 1931
AMPULLELLA PERUVIANA, n. sp.
Pl. 127, fig. 2,3

Material.—The holotype (G. 71534), one figured paratype (G. 71535) and two less complete paratypes (G. 71536–7). Also three smaller specimens which probably consist of the early whorls of the species.

Description.—Large, anomphalous, almost biconical, height considerably exceeding diameter. Whorls more or less adpressed at suture, the earlier ones low and feebly convex, forming a slightly cyrtoconoid top to spire, with an apical angle of about 90°; later whorls increasing in relative height owing to a steepening of the sutural slope and becoming strongly concave in outline through the presence of a broad spiral depression which appears at about the origin of the penultimate whorl, slightly above the middle of its height, and continues to the outer lip. Last whorl broadly rounded at the periphery, and with its base flattened-convex in outline as far as the spirally ascending angulation which lies to the left of the inner lip. Aperture pyriform, its height exceeding that of the spire. Outer lip and growth lines strongly prosocline, slightly sigmoidal. Inductura relatively thin, not spreading over base, its edge almost in alignment with margin of columellar lip. Shell wall thick.

Measurements.—Holotype: height (apertural margin restored) ca. 80 mm., diameter 58 mm. Largest paratype: height (apex restored) ca. 100 mm., diameter 65.5 mm.

Remarks.—The most closely comparable described species are from the Upper Jurassic of Europe. In the English Portlandian species, *Ampullella elegans* (J. de C. Sowerby) (1836, p. 347, pl. 33, fig. 3), the proportions of the shell are about the same, but the whorls have a narrow sutural ledge and lack the well-defined spiral depression which appears on the later ones in the new species. The French Portlandian species, *A. beaugrandi* (de Loriol) (1874, p. 344, pl. 8, fig. 22*a*,*b*), has a broader spiral depression which produces almost an angularity of the periphery of the last whorl, and the height of its spire slightly exceeds that of the aperture.

Locality.—One km. E by S of Puerto Caballa.

Family NERINEIDAE
Genus COSSMANNEA Pchelintsev, 1927
COSSMANNEA NASCAENSIS, n. sp.
Pl. 127, fig. 4–6

Material.—The holotype (G. 71543) and five paratypes (G. 71541–2, 44–6).

Description.—Of medium size, very acute,

EXPLANATION OF PLATE 128

Illustrations are of natural size. Localities are given in text. Registration numbers are those of the Geological Department of the British Museum (Natural History).

FIG. *1*—*Lima* (*Plagiostoma*) cf. *L.* (*P.*) *alticosta* Chapuis & Dewalque. L.88533.
2—*Lucina* cf. *L. bellona* d'Orbigny. L.88539.
3—*Pleuromya uniformis* J. Sowerby L.88551.
4—*Lucina goliath* Gottsche. L.88553.
5,6—*Trigonia stelzneri* Gottsche. L.88540, L.88541.
7—*Cercomya peruviana*, n. sp. Holotype, L.88543.
8—*Cercomya undulata* (J. de C. Sowerby). L.88542.

anomphalous. Whorls strongly concave, with a bulging sutural region; their height is only slightly less than their diameter. Surface smooth. Three internal folds present, of which the columellar is prominent, angular, and at about one-third of whorl height, the parietal angular and slightly less prominent, and the labral prominent but bluntly rounded.

Measurements.—The maximum diameter is about 10 mm. The specimens all lack the apical whorls and their original height is difficult to estimate accurately.

Remarks.—The generic name *Cossmannea* (type *Nerinea desvoidyi* d'Orbigny) is here employed for the group of species with strongly concave whorls, a bulging sutural region, and 2–3 internal folds, considered by Cossmann (1898) to constitute *Nerinea* s.s. I have shown elsewhere (Cox, 1949) that a species of another group should be accepted as type species of *Nerinea*. Some highly acute species like the one now described have been referred to *Nerinella* Sharpe, but that genus is best restricted to forms in which the later whorls are not strongly concave and the ornament resembles that of the Turritellidae. Of European Jurassic species, "*Nerinea*" *contorta* Buvignier (Cossmann, 1898, p. 50, pl. 7, fig. 12,13), from the Rauracian, most closely resembles the species now described, but has whorls which are slightly higher in proportion to their diameter.

Locality.—Four km. upstream from mouth of Río Grande.

Cossmannea peruviana, n. sp.
Pl. 127, fig. 7,8

Material.—The holotype (G. 71515) and five paratypes (G. 71516–20), all incomplete.

Description.—Of medium size and moderate acuteness, anomphalous. Whorls relatively low, their height about one-half of their maximum diameter, strongly concave, with the sutural region forming a narrow, angular bulge, on the adapical side of the most projecting part of which the suture itself, which is obscure, appears to lie. Erosion produces a jagged edge to this angular bulge. A prominent, rounded labral fold is present, but in the specimen sectioned axially as the most promising for the purpose, other internal features proved to be obscure.

Measurements.—Original height of largest specimen ca. 58 mm., maximum diameter ca. 12 mm.

Remarks.—The narrowness and pronounced angularity of the bulging sutural region are the distinctive features of this species. The most closely comparable European species is "*Nerinea*" *carinata* Piette (Cossmann, 1898, p. 27, pl. 2, fig. 29–31), from the upper Bathonian of France, which appears to be slightly less acute. "*N.*" *carinata*, like the Peruvian species, has a prominent labral fold; according to Cossmann its columella has only an oblique swelling and its parietal fold is almost invisible.

Locality.—Four km. upstream from mouth of Río Grande.

Genus Nerinella Sharpe, 1850
Nerinella caballensis, n. sp.
Pl. 127, fig. 9–12

Material.—The holotype (G. 71523) and seven paratypes (G. 71524–30).

Description.—Small, moderately acute, anomphalous. Whorls concave, relatively low, their diameter equal to about twice their height, carrying usually three, occasionally four, spiral threads on their concave region. One prominent, rather narrow labral fold, median in position; no columellar or parietal fold observable in a specimen sectioned (its internal structure is, however, partly obscured by calcite of secondary origin).

Measurements.—Original maximum height ca. 35 mm., maximum diameter 8 mm.

Remarks.—A closely related species is *Nerinella maudensis* (Whiteaves) (1884, p. 214, pl. 27, fig. 2, 2*a–d*), from the eastern end of Maude Island, British Columbia, where it probably came from the Bajocian Lower Yakoun formation.[1] *N. maudensis*, like the Peruvian species, has only one internal fold, on the outer wall. It appears, from the figures, to differ in its slightly higher whorls and more numerous spiral threads.

Locality.—1.4 km. E by S of Puerto Caballa.

[1] See McLearn, 1949, p. 16, for an incomplete list of fossils from this formation, including ammonites which, according to Whiteaves (1884, p. 255), were from the same beds as *N. maudensis*. McLearn does not mention the *Nerinella*.

Class PELECYPODA
Family PECTINIDAE
Genus ENTOLIUM Meek, 1865
ENTOLIUM DEMISSUM (Phillips)

Pectin demissus PHILLIPS, 1829, Geol. Yorkshire, vol. 1, p. 140, pl. 6, fig. 5.; PHILIPPI, R. A., 1899, Fósiles secundarios de Chile, p. 35, pl. 20, fig. 3.
Pectin (Entolium) disciformis Schübler, BURCKHARDT, 1900, Mus. La Plata Anales (Sec. Geol. Min.), vol. 2, p. 24, pl. 19, fig. 11; p. 32, pl. 21, fig. 2.; WEAVER, 1931, Univ. Washington Mem. 1, p. 273, pl. 28, fig. 170.

Material.—Four imperfect specimens.

Remarks.—This well-known species has been recorded previously, often under the synonymous name *Entolium disciforme* (Zieten), from a number of localities in the Cordillera of Argentina and Chile. In South America it usually occurs in beds assigned to the Bajocian, but it has also been recorded from the upper Lias of Argentina. In Europe its range extends from the upper Lias to the Oxfordian.

Locality.—Four km. upstream from mouth of the Río Grande.

Family LIMIDAE
Genus LIMA Cuvier, 1798
Subgenus PLAGIOSTOMA J. Sowerby, 1814
LIMA (PLAGIOSTOMA) cf. L. (P.) ALTICOSTA Chapuis & Dewalque
Pl. 128, fig. 1

[cf.] *Lima alticosta* CHAPUIS & DEWALQUE, 1853, Acad. roy. Belgique Mém. cour. vol. 25, p. 203, pl. 28, fig. *3a-c.*
[cf.] *Lima (Plagiostoma) alticosta* Chap. & Dew., Cox, 1943, Malac. Soc. London Proc., vol. 25, p. 168, pl. 18, fig. 46–48.

Material.—Two specimens (L 88533–4).

Description.—In the better preserved of the specimens, both of which are imperfect and somewhat distorted, the length exceeds the height, the umbonal angle is obtuse (about 120°), and the shell is not markedly inequilateral, the anterior umbonal ridge being short and not well defined and the ventral margin symmetrical and strongly convex. There are over 40 narrow ribs, separated by slightly unequal, flat interspaces of considerably greater width. The ribs are slightly sinuous and have sides which converge to some extent from their base to their rounded top, and their height is usually rather less than their basal width, although it is difficult to say to what extent it has been reduced by erosion. The ribs extend on to the posterior auricle. The height of the larger specimen is about 67 mm.

Remarks.—The comparatively equilateral outline of these specimens and the lack of any pronounced oblique elongation of the shell in an antero-ventral direction suggests comparison with the English Inferior Oolite species, *Lima alticosta*, and the slightly less equilateral "*Plagiostoma sulcatum gingense*" of Quenstedt (1856, p. 380, pl. 51, fig. 2), which I (Cox, 1943) have placed in its synonymy, although Dechaseaux (1936, p. 37, pl. 3, fig. 5) has regarded it as specifically distinct. As its name indicates, *L. alticosta*, in its most typical form, is characterized by high, square-cut ribs, but among specimens in the British Museum (Natural History) which appear to be referable to this species are some (Cox, 1943, pl, 18, fig. 46) in which the ribs are lower and more round-topped than in the more typical specimens. Erosion, either during life or after, may have produced this effect. The slight sinuosity of the ribs is one of the features of *L. alticosta*. In English Inferior Oolite specimens which appear referable to the species the number of ribs ranges from 26 to 67. Dechaseaux gives the number as 42–46, which is approximately the same as in the specimens now described. The presence of ribs on the posterior auricle, apparent in one of these specimens, contrasts, however, with the smoothness of this auricle in the typical *L. alticosta*, so that identification with that species must be qualified.

Locality.—Four km. upstream from mouth of Río Grande.

Genus CTENOSTREON Eichwald, 1862
CTENOSTREON PECTINIFORME (Schlotheim)

Ostracites pectiniformis SCHLOTHEIM, 1820, Petrefactenkunde, p. 231.
Lima rustica HUPPÉ, 1854, *in* Gay, Historia Chile, Zool., vol. 8, p. 295, pl. 4, fig. 6 (non Young & Bird, 1828).
Ctenostreon Wrighti Bayle, STEINMANN, 1929, Geologie von Perú, pp. 76, 78, text-fig. 89.

Material.—Four specimens.

Remarks.—These specimens, which have 11–12 ribs, agree well with the one from the Inferior Oolite of Peru figured by Steinmann as *Ctenostreon wrighti* Bayle, under which name Jaworski had already recorded specimens from the Dogger of Argentina. *C. wrighti* was founded by Bayle on a specimen

from the Inferior Oolite of Leckhampton, near Cheltenham, England, and has been regarded by British authors as a synonym of *C. pectiniforme*, which was originally described from the Inferior Oolite of Germany. *C. pectiniforme* itself has been recorded by several authors from the Dogger of Argentina and Chile, and there is little doubt that Huppé's *Lima rustica*, from Chile, should be included in its synonymy.

Locality.—Four km. upstream from mouth of Río Grande.

Family TRIGONIIDAE
Genus TRIGONIA Bruguière, 1789
TRIGONIA STELZNERI Gottsche
Pl. 128, fig. 5,6

Trigonia Stelzneri GOTTSCHE, 1878, Palaeontographica, Supp. 3, Lief. 2, Abt. 3, p. 24, pl. 6, fig. 1.; MÖRICKE, 1894, Neues Jahrb., Beil.-Bd. 9, p. 50.; TORNQUIST, 1898, Pal. Abhandl., n.F., Bd. 4, p. 165; LAMBERT, 1944, Mus. La Plata, Revista, n. ser. (sec. Pal.), vol. 2, p. 364, pl. 2, fig. 6,7.

Material.—Two specimens (L. 88540–1).

Remarks.—These are costate trigonias in which the height is considerably in excess of the length and the moderately wide-spaced costae lose their regular concentric arrangement near the anterior margin, bending first up and then down. A similar irregularity is well shown in Gottsche's original figures of the species, the type locality of which was Espinazito, in the Argentinian Cordillera, where the beds are of Bajocian age. Möricke subsequently recorded it from the Inferior Oolite of Chile. A specimen from the Callovian of Neuquen (Argentina) referred to it by Weaver (1931, p. 240, pl. 20, fig. 103,104) was a relatively elongate costate *Trigonia* which was almost certainly misidentified. The most similar species from the European Jurassic is *T. elongata* J. de C. Sowerby, which first appears in the Fuller's Earth and occurs again in the Cornbrash. Its ribs are not so irregular at their anterior end as in the South American species.

Locality.—Four km. upstream from mouth of Río Grande.

Family LUCINIDAE
Genus LUCINA Lamarck, 1799
LUCINA cf. L. BELLONA d'Orbigny
Pl. 128, fig. 2

[cf.] *Lucina lyrata* Phillips var. *transversa* D'ARCHIAC, 1843, Soc. géol. France Mém., vol. 5, p. 372, pl. 26, fig. 3*a-c*.

[cf.] *Lima Bellona* D'ORBIGNY, 1850, Prodrome, vol. 1, p. 309; MORRIS & LYCETT, 1853, Mollusca from the Great Oolite, Bivalves, p. 67, pl. 6, fig. 18,18a; MARZLOFF, 1936, Lab. géol. Lyon Trav., fasc. 28, p. 101, pl. 11, fig. 19–21.

Material—One specimen (L. 88539).

Remarks.—The specimen is an internal mould 55 mm. long, bearing traces of thin concentric ridges which are up to 6 mm. apart. In shape it agrees well with the internal mould from England represented by Morris & Lycett in their fig. 18a, but its concentric ridges are more wide-spaced than in European specimens, so that it seems desirable to qualify its identification. Oppel (1856, p. 529 [409]) briefly described a new species *Lucina wrighti*, placing in its synonymy "*L. bellona* Morris and Lycett *pars*." His intention was to distinguish a form which occurs in the Inferior Oolite, and was possibly represented by fig. 18a of Morris & Lycett, from the typical *L. bellona* of the Great Oolite, but it is doubtful if specimens from the two formations can be separated specifically. In Europe *L. bellona* first appears in the upper Lias. Jaworski (1914, p. 299) has reported its presence in the Dogger of Piedra pintada, Argentina, but has given no figures or detailed description of the specimens.

Locality.—Four km. upstream from mouth of Río Grande.

LUCINA GOLIATH Gottsche
Pl. 128, fig. 4

Lucina goliath GOTTSCHE, 1878, Palaeontographica, Supp. 3, Lief. 2, Abt. 3, p. 28, pl. 5, fig. 11.; JAWORSKI, 1915, p. 446.; STEINMANN, 1929, Geologie von Perú, p. 78,79, text-fig. 92.

Material.—Two specimens (L. 88552-3).

Remarks.—Gottsche founded this species upon a very incomplete right valve from the Inferior Oolite of the Espinazito pass, in the Argentinian Cordillera, but Steinmann's subsequent figure of a specimen from the Inferior Oolite of Chunumayo, Peru, was rather more satisfactory. No adequate description of the species has, however, been published. Concentric ridges appear to have been more marked and evenly spaced in Steinmann's specimen than in Gottsche's. Gottsche figured the hinge of his type specimen, the chief feature being a large, blunt sub-umbonal tooth, but at present it is only possible to refer the species to *Lucina*, sensu lato.

The specimens now recorded are well inflated shells with an oval outline and a rather narrowly rounded anterior extremity situated above mid-height. The posterior end is not well preserved, but does not appear to have been truncated. The ventral margin is rather strongly convex; in one specimen it undulates irregularly at its anterior end, possibly owing to some accident in growth. The surface bears irregular concentric rugae, regular ridges like those represented in Steinmann's figure being absent. In both specimens the dorsal region is obscured by adherent matrix. When complete, the better preserved one was about 65 mm. long and 55 mm. high. It is preserved with its two valves partly opened along the ventral margin, thus increasing its apparent convexity. The convexity of each valve is about 17.5 mm.

Locality.—1.4 km. E by S of Puerto Caballa.

Family PLEUROMYIDAE
Genus PLEUROMYA Agassiz, 1842
PLEUROMYA UNIFORMIS (J. Sowerby)
Pl. 128, fig. 3

Unio uniformis J. SOWERBY, 1813, Mineral Conchology, vol. 1, p. 83, pl. 33, fig. 4.
Pleuromya jurassi AGÁSSIZ, GOTTSCHE, 1879, Palaeontographica, Supp. 3, Lief. 2, Abt. 3, p. 32, pl. 7, fig. 5a,b; BURCKHARDT, 1900, Mus. La Plata Anales (Sec. Geol. Min.), vol. 2, p. 35, pl. 21, fig. 12,13.

Material.—Several specimens.

Remarks.—In view of its priority, the name *P. uniformis* has now come into general use for the *Pleuromya* which is widespread in the Jurassic of Europe, where it ranges from the Inferior Oolite to the Portland beds and was formerly known by the specific names *jurassi* (Brongniart), *decurtata* (Phillips), *tellina* Agassiz and *voltzi* Agassiz. Records of the Liassic species *P. striatula* Agassiz from the Inferior Oolite of Argentina may also refer to *P. uniformis*. The specimens from that country recorded by Gottsche and Burckhardt as *P. jurassi* were of Bajocian age.

Locality.—Four km. upstream from mouth of Río Grande.

Family LATERNULIDAE
Genus CERCOMYA Agassiz, 1843
CERCOMYA UNDULATA (J. de C. Sowerby)
Pl. 128, fig. 8

Sanguinolaria undulata J. DE C. SOWERBY, 1827, Mineral Conchology, vol. 6, p. 91, pl. 548, fig. 1,2.
Cercomya pinguis AGASSIZ, 1843, Monographie des Myes, p. 145, pl. 11, fig. 19–21; pl. 11a, fig. 17,18.
Cercomya Inglesia MÖRICKE, 1894, Neues Jahrb., Beil.-Bd. 9, p. 58, pl. 2, fig. 8.
Cercomya undulata MÖRICKE, 1894, loc. cit., p. 58.

Material.—One specimen (L. 88542).

Remarks.—The specimen is about 35 mm. high; its posterior end is now broken away, but its original length was probably about 90 mm. It agrees well with specimens of *C. undulata* from Europe, where the range of the species is from the Bajocian to the Oxfordian or higher. *C. pinguis* must be regarded as a synonym, as suspected by Agassiz himself, and I see no reason for the separation of Möricke's *C. inglesia*. The last author recorded *C. undulata* from the Inferior Oolite of Chile, and his *C. inglesia* was either of upper Liassic or of Inferior Oolite age.

Locality.—Four km. upstream from mouth of Río Grande.

CERCOMYA PERUVIANA, n. sp.
Pl. 128, fig. 7

Material.—The holotype only (L. 88543).

Description.—Of medium size, resembling *C. undulata* in shape, allowing for the fact that its posterior extremity is broken away. A slightly convex, smooth area, running from the umbo perpendicularly to the ventral margin and distinctly limited by a faint ridge on the anterior side, separates an anterior part of the surface bearing strong concentric folds from a posterior part which has rather unevenly spaced radial threads but no concentric ornament except growth lines; the threads are most closely arranged posteriorly and are eight in number on the part of the surface still preserved (it is improbable that more were present).

Measurements.—Original length (estimated) 75 mm., height 30 mm.

Remarks.—This species much resembles *Cercomya punctata* Stanton (1899, p. 628, pl. 74, fig. 5), from beds of probably Callovian age in the Yellowstone National Park, a species with which *C. semiradiata* Whiteaves (1900, p. 288, pl. 37, fig. 4), from the Callovian upper Yakoun formation of British Columbia (see McLearn, 1949, p. 11), appears synonymous. McLearn (1924,

p. 56, pl. 9, fig. 11) has figured a distorted specimen, the specific identification of which does not seem to have needed qualifying, from the Callovian Fernie formation of Alberta, Canada. In *C. punctata*, however, the radial threads on the posterior part of the surface appear to be weaker and more crowded than in the species now described and the smooth median sector is wider. *C. versicostata* (Buvignier) (1852, p. 10, pl. 9, fig. 11–13), with which *C. magnifica* (Contejean) (1860, p. 349, pl. 27, fig. 1,2) is synonymous, is a comparable species found in the Kimmeridgian of Europe, but its radial threads carry beads.

Locality.—Four km. upstream from mouth of Río Grande.

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MANUSCRIPT RECEIVED FEBRUARY 1, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, p. 1187–1192, 1 TEXT-FIG., SEPTEMBER 1956

PLEISTOCENE MAMMALS OF THE BERENDS FAUNA OF OKLAHOMA

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ABSTRACT—Fourteen species of mammals from the Illinoian (?) Berends local fauna from Beaver County, Oklahoma, are listed, and two of these are described as new (Rodentia: *Ondatra triradicatus*, *Peromyscus berendsensis*). An additional fossil mammal, from a nearby locality thought to be of the same age, is described as a new genus and species (Rodentia: *Burosor effossorius*). On the basis of paleoecological evidence derived from an analysis of the mammalian fauna, it is postulated that the Berends local fauna existed in a cool, moist climate, probably at a time of glaciation in North America.

INTRODUCTION

DURING the past nine years field parties from the University of Michigan Museum of Paleontology, under the direction of Dr. Claude W. Hibbard, have been working in Pleistocene deposits in northwestern Oklahoma and southwestern Kansas. From this work has come material representing a series of faunas which apparently correspond with the generally accepted glacial and interglacial subdivisions of the Pleistocene Epoch. In 1950 and 1951, Dr. Hibbard and party worked post-Pearlette Ash deposits 4.5 miles north and 1 mile west of Gate, Beaver County, Oklahoma. At this locality was discovered a new fauna which has since been considered as probably Illinoian (Hibbard, 1953) on the basis of the vertebrates present. Taylor (1954) named this the Berends local fauna in a paper dealing with the associated mollusks from the same site. Subsequent work by the University of Michigan field parties at the same locality during the summers of 1952, 1953 and 1954 has turned up a mammalian fauna of considerable interest in relation to the Pleistocene picture. It is, therefore, the purpose of this paper to bring together the previously published mammal records from the Berends local fauna (Rinker & Hibbard, 1952; Taylor, 1954; Smith, 1954) and to present records of mammals which have since been taken from the Berends site. In addition, one record, not a part of the Berends local fauna, is included because it comes from a locality approximately one mile from the Berends site and is, in all probability, of the same age as the Berends specimens.

The numbers referred to in the following systematic list are the catalogue numbers of the University of Michigan Museum of Paleontology, where the specimens are deposited.

THE BERENDS MAMMAL FAUNA

Order INSECTIVORA

Family SORICIDAE

SOREX cf. S. CINEREUS Kerr

No. 31791, the posterior portion of a right ramus with M_1–M_2, and No. 31792, the posterior portion of a left ramus with M_1-M_3, most closely resemble the living common shrew and are therefore referred to this species.

BLARINA cf. B. BREVICAUDA (Say)

No. 31790, a fragment of a right ramus with M_1–M_2, is referred to this species since it is almost indistinguishable from teeth and jaws of the living shorttail shrew.

Order CARNIVORA

Family CANIDAE

CANIS LATRANS Say

A coyote is represented by No. 29010, a complete metatarsal and a fragment of another, and No. 33319, a fragment, 59.4 mm. long, of a right mandibular ramus with the alveoli of M_2 and M_3 and partial alveolus of M_1.

Order RODENTIA

Family CASTORIDAE

CASTOROIDES sp.

No. 29009, including parts of several limb bones and numerous tooth fragments, represents this giant beaver.

PARADIPOIDES STOVALLI Rinker & Hibbard

The following material is assigned to this species of extinct beaver: No. 27286, the holotype, a fragment of a right ramus with M_1–M_2; No. 33323, an isolated right P^4; and No. 31787, two teeth and a right second metacarpal, the latter definitely from a beaver and a little longer and slightly heavier than that of the living *Castor canadensis* Kuhl.

Family GEOMYIDAE
GEOMYS sp.
Text-fig. 1,K

The following material, unidentifiable to species, is referred to this genus of living pocket gophers: No. 28114, which consists of several fragments including part of a left maxilla and premaxilla with incisor, a left ramus without incisor (Text-fig. 1, K), upper cheek-teeth in a maxilla fragment, and sacral vertebrae with portions of both innominate bones; No. 31778, an isolated P^4; No. 31786, a right ramus with incisor; and No. 33320, the proximal portion of a right femur.

Family HETEROMYIDAE
PEROGNATHUS cf. P. HISPIDUS Baird

An isolated right upper incisor, No. 31785, was indistinguishable from those of specimens of this living species of pocket mouse.

Family CRICETIDAE
PEROMYSCUS BERENDSENSIS, n. sp.
Text-fig. 1, A

Holotype.—No. 31789, anterior portion of right ramus with incisor, M_1 and the alveoli of M_2–M_3. Collected summer of 1953 by Claude W. Hibbard and field party.

Horizon and type locality.—Late Middle Pleistocene, Illinoian (?), in age. Southeast corner of Sec. 6, T. 5 N., R. 28 E. C. M., Beaver County, Oklahoma.

Diagnosis.—M_1 definitely shorter and narrower, by actual measurement, than those of the similar fossil *Peromyscus* with which it was compared (*P. cochrani* Hibbard, *P. baumgartneri* Hibbard, *P. cragini* Hibbard), being closest in width to that of *P. cragini* and closest in length to that of *P. baumgartneri* paratype U.M.M.P. No. 30546. *Peromyscus maniculatus* (Wagner), the Recent species (deer mouse) with M_1 most closely resembling that of *P. berendsensis*, has in general a more complicated cusp pattern. Several of the short-tailed forms, however, *P. maniculatus bairdi* (Hoy and Kennicott) in particular, do show a fairly close similarity to *P. berendsensis* in M_1 conformation. The M_1 of this living form differs from that of the fossil by being wider and longer. In addition, the posterior slopes of the cusps of the *P. m. bairdi* tooth are steeper than those of the *P. berendsensis* tooth and the anteroconid is divided, which it is not in the fossil form. The mental foramen is closer to the base of the M_1 in *P. berendsensis* than it is in any of the other forms compared, fossil or Recent. Finally, the incisor of the Berends form is broader than those of the other fossil species.

Description of holotype.—The mandible and teeth are those of a moderately small *Peromyscus*, the size of the M_1 closely approximating that of the living species *Peromyscus polionotus* (Wagner). The mental foramen is located very close to the base of the M_1. The M_1 measures: 1.4 mm. greatest length and 0.9 mm. greatest width. A small mesolophid is present although there is no indication of a mesostylid. The cusps are moderately worn, indicating at least an adult animal. The incisor is quite broad and the tooth has a generally heavy appearance.

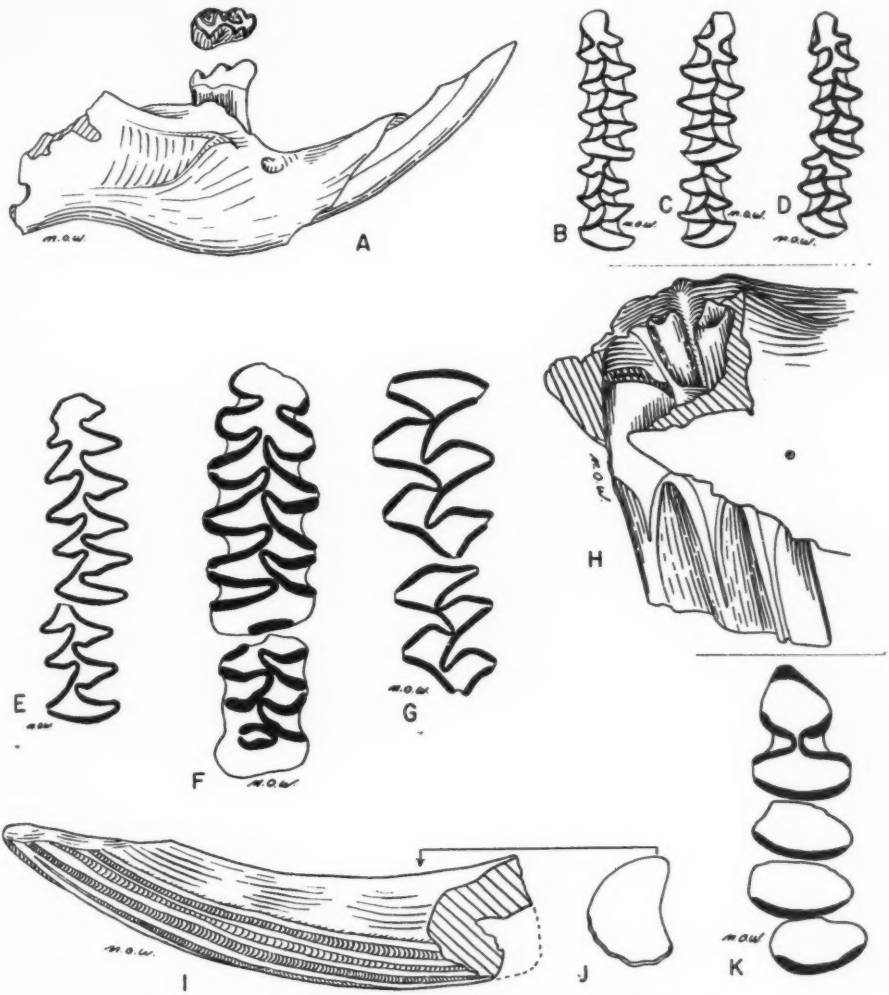
ONDATRA TRIRADICATUS, n. sp.
Text-fig. 1, E–H

Holotype.—No. 31781, fragment of left maxilla with M^1–M^2. Collected summer of 1953 by Claude W. Hibbard and field party (Text-fig. 1, G, H).

Horizon and type locality.—Late Middle Pleistocene, Illinoian (?), in age. Southeast corner of Sec. 6, T. 5 N., R. 28 E. C. M., Beaver County, Oklahoma.

Diagnosis.—Teeth well rooted, M^1 having three well developed roots, thus differing from that of the Recent muskrat, *Ondatra zibethicus* (Linn.), which characteristicaly has only two. The teeth are smaller than those of *O. zibethicus* and larger than those of *O. nebrascensis* (Hollister) and *Neofiber alleni* True.

Description of holotype.—The maxilla and teeth are those of an adult muskrat. A break in the side of the maxilla makes visible the three distinct roots of the M^1 which are



TEXT-FIG. *1*—Some rodents from the Illinoian (?) of Oklahoma.
A—Peromyscus berendsensis, n. sp., UMMP 31789, holotype, lateral view and occlusal view of M_1, ×6.
B,C—Microtus pennsylvanicus (Ord), *B*. UMMP 31773, left M_1 and M_2, occlusal view, ×6. *C*, UMMP 31774, right M_1 and M_2, occlusal view, ×6.
D—Pedomys cf. *P. ochrogaster* (Wagner), UMMP 31775, left M_1 and M_2, occlusal view, ×6.
E-H—Ondatra triradicatus, n. sp. *E*, UMMP 33391, paratype, left M_1 and M_2 of young specimen, occlusal view, ×5. *F*, UMMP 33322, paratype, right M_1 and M_2 of old adult, occlusal view, ×5. *G*, UMMP 31781, holotype, left M^1 and M^2, occlusal view, ×5. *H*, UMMP 31781, holotype, dorsal lateral view of maxillary fragment with M^1 in place, showing the three prominent roots, ×5.
I,J—Burosor effossorius, n. gen. n. sp. *I*, UMMP 21184, holotype, lateral view, ×1. *J*. UMMP 21184, holotype, cross section taken at region indicated in *I*, ×1.
K—Geomys sp., UMMP 28114, left P^4, M^1-M^3 occlusal view, ×6.
Drawings by Michael O. Woodburne.

separate for at least ⅔ of the length of the tooth below the alveolar border. Alveolar length of combined M^1–M^2, 10.7 mm.; greatest width of M^1, 3.2 mm.; that of M^2, 2.8 mm.; length of occlusal surface of M^1, 4.7 mm.; that of M^2, 3.9 mm. The teeth, then, are obviously smaller than those of *O. zibethicus*. The conformation of loops and

reentrant angles and amount of broken enamel pattern on the sides of loops fall within the range of variation of *O. zibethicus*. The reticulated appearance of the cement in the reentrant angles is also like that of the latter species.

Description of paratypes.—No. 31780 is an isolated RM^3, two-rooted as in *Ondatra zibethicus* but agreeing in size with the teeth of the holotype. No. 31792, undoubtedly *Ondrata triradicatus*, consists of the following: an isolated RM^1 with the posterior loop and two anterior roots missing, corresponding in dimensions and amount of wear with the LM^1 of the holotype and showing very well the extent of the root formation; parts of two upper incisors (right and left) which agree closely in curvature with incisors of *O. zibethicus* but are narrower than those of most specimens of the latter species (although they do fall within the range of variation of *O. zibethicus*); parts of LM_2 and LM_3 of very young animals which, except for their smaller size, resemble those of *O. zibethicus* of comparable age; and two fragments of the palatal region of maxillae showing parts of the molar alveoli. On each of the latter bones, the length of the maxilla between the anterior border of the palatine bone and the anterior palatine foramina is considerably less than that of either *Ondatra zibethicus* or *Neofiber alleni*. No. 33391 is a left mandible fragment of a young animal with M_1–M_2 (Text-fig. 1, E), and No. 33322, a right mandible fragment, including M_1–M_2 and part of the alveolus of M_3, from an old adult (Text-fig. 1, F). The teeth of the young individual are short-rooted and fit into the 180–210 day-old stage shown by Galbreath (1954, p. 240) for *Ondatra zibethicus*. The teeth of the adult, on the other hand, are quite worn, show definite, well-developed roots, and probably fall into Galbreath's 500–600 day-old stage. It is of interest that the M_2 and M_3 listed above under No. 31792 apparently belong to an age class below the 90–120 day-old stage of Galbreath, thereby presenting for this species an unusually complete age series.

Referred material.—No. 33321 consists of a collection of bones and fragments which are all those of small muskrats and are therefore referred to this species. These are: one complete ulna, a complete tibia without fibula, a portion of another tibia, a metatarsal, a calcaneum, the distal portion of a lower incisor, and two interorbital fragments of frontal bones.

The designation *triradicatus*, the Latin word meaning "three-rooted," refers to the diagnostic feature of the M^1 of this species.

MICROTUS PENNSYLVANICUS (Ord)
Text-fig. 1, B, C

No. 31773, a fragment of a left ramus with M_1–M_2 (Text-fig. 1, B), No. 31774, a fragment of a right ramus with M_1–M_2 (Text-fig. 1, C), and No. 31777, a fragment of a left maxilla with M^1, apparently belong to the same species as the living meadow vole.

PEDOMYS cf. P. OCHROGASTER (Wagner)
Text-fig. 1, D

No. 31775, a fragment of a left ramus with M_1–M_2 (Text-fig. 1,D), and No. 31776, consisting of numerous isolated cheekteeth, are assigned to the species of the present-day prairie vole.

Order PERISSODACTYLA
Family EQUIDAE
EQUUS (s.s.) sp.

The true horses are represented by No. 29152, metacarpal and molar teeth fragments, and No. 31771, tooth and longbone fragments.

Order LAGOMORPHA
Family LEPORIDAE

No. 31783 is a single tooth, a lower left P_4, M_1, or M_2, from a leporid the size of a large *Sylvilagus* (rabbit) or a small *Lepus* (jackrabbit or hare), which is not identifiable to genus.

Order PROBOSCIDEA
Family ELEPHANTIDAE
MAMMUTHUS cf. M. COLUMBI Falconer

Two uncatalogued fragments of molar teeth are assigned to this species of mammoth.

A NEW GENUS AND SPECIES OF GIANT RODENT

Order RODENTIA
Family SCIURIDAE (?)
Genus BUROSOR, n. gen.
Genotype:—*Burosor effossorius*, n. sp.

Diagnosis.—The holotype is apparently the tooth of a large rodent, of approximately

the same size as the giant beaver, *Castoroides*. The pointed shape of the tip and nearly triangular cross-section of the tooth serve to distinguish this genus and species from any of the known beavers and to make highly improbable a relationship with any of the large South American hystricomorph rodents (*Cuniculus*, *Hydrochoerus*, etc. . . .).

BUROSOR EFFOSSORIUS, n. sp.
Text-fig. 1,I,J

Holotype.—No. 21184, distal portion of isolated lower left incisor. Purchased from G. O. Raasch, 1939.

Horizon and type locality.—Late Middle Pleistocene, Illinoian (?), in age. Five miles north of Gate, Beaver County, Oklahoma.

Description of holotype.—The tooth is 70.1 mm. long, 14.9 mm. maximum depth, and 11.1 mm. maximum width. The end of the tooth does not have a flat cutting surface but comes to a somewhat worn point, suggesting that its function was that of a root-grubbing tool and not a chiseling or cutting device. The cross section of the tooth is almost triangular with the ventro-lateral surface being the shortest side and covered with enamel. The enamel is grooved, forming 7 narrow ridges which do not branch or connect with one another. The mesial surface of the tooth is somewhat flattened with a shallow trough running lengthwise along the middle for about two-thirds of the length from the proximal end; the other two sides are slightly convex.

Remarks.—The classification of this specimen to order and family is necessarily tentative since the tooth is unlike that of any other described mammal. It seems relatively certain, however, that it is an incisor of a rodent, albeit a very large one. It differs in shape from that of any known beaver, although there is yet at least one more beaver or beaver-like form in the Berends local fauna which has been left undescribed due to the lack of adequate material for comparison, and for which the lower incisors are not known. It most closely resembles the sciurid line, represented particularly by *Paenemarmota* Hibbard & Schultz (1948), and is therefore tentatively placed in the family Sciuridae. The shape and type of enamel ridging on it are most suggestive of the marmots (although *Castoroides* has similar ridging on the incisors), but the type of tooth wear is certainly not that of a typical rodent of any sort. A rooting or grubbing use is the most likely one which may be postulated from its appearance.

The scientific name, meaning "huge gnawer adapted for digging up," refers to the holotype and its interpreted function, and is formed from the Latin (bu—huge, rosor from rodo—to gnaw; effossorius from effodio—to dig up, or to dig out).

DISCUSSION

On the basis of the mollusks and fish found in the Berends local fauna, Taylor (1954, p. 8) and Smith (1954, p. 288) postulated that this fauna existed at a time of cool, moist climate. The presence of fir, spruce and pine pollens in the deposit (Smith, 1954) does not necessarily indicate forest conditions, but rather it tends to point up the fact that the climate was cool and more moist than at present. The assemblage of species reported on in the present paper seems to corroborate these assumptions. All of the extant North American forms listed may be found in North Dakota today, although not all in the same habitat. It is of additional interest that Taylor & Hibbard (1955, p. 6–7), in discussing the Illinoian (?) Bar M local fauna [37 species of molluscs and an armadillo, *Dasypus bellus* (Simpson)] from Harper County, Oklahoma, postulate that "a climate with summers like those of North Dakota, and with winters no colder and perhaps warmer than those of northern Kansas" prevailed during that period as indicated by the mollusks.

The Berends mammal fauna seems to represent at least two habitat types: an upland fauna and a low ground or marsh fauna. Such animals as the prairie vole (*Pedomys*), pocket gopher (*Geomys*), pocket mouse (*Perognathus*), and possibly *Burosor* (if it is a sciurid) represent the drier habitats, whereas the meadow vole (*Microtus*), shrews (*Blarina*, *Sorex*), muskrat (*Ondatra*) and the beavers definitely belong to moist or marshy situations. In addition, the general aspect of the molluscan fauna and the presence of a white pelican (*Pelecanus erythrorhynchos* Gmelin) (Mengel, 1952), seems to indicate a lake habitat. The larger forms like the coyote and the horse probably ranged on the dry plains and came to the lake for water, and the mammoth was most likely an inter-

mediate form living in the valleys but not in the marsh habitat. As these animals come from deposits which were located in a basin which apparently was a lake at some time during its development (Rinker & Hibbard, 1952, p. 98; Taylor, 1954, p. 6), it is easy to see how these faunal elements would come to be found together.

It is reasonable to postulate then (Hibbard, 1953) on the basis of the paleoecological evidence provided by the make-up of the Berends local fauna, that the cool, moist climate indicated belonged to a time of glaciation in North America.

SUMMARY

The Berends local mammalian fauna consists of 14 species, two of which are recognized as new and described, from the Illinoian (?) of Oklahoma. An additional fossil mammal, from a nearby deposit thought to be of the same age, is included and described as a new genus and species. The paleoecological evidence derived from a faunal analysis of this assemblage together with 33 species of mollusks (Taylor, 1954; Taylor & Hibbard, 1955), 14 species of fish (Smith, 1954) and one bird species (Mengel, 1952) belonging to this same fauna, indicates that the Berends local fauna existed in a cool, moist climate, probably during a time of glaciation in North America.

ACKNOWLEDGMENTS

I am indebted to Dr. Claude W. Hibbard for the opportunity to work up this fauna and for his numerous invaluable suggestions and criticisms concerning the identification of specimens and the preparation of this paper.

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MANUSCRIPT RECEIVED APRIL 2, 1956.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1193–1198, PL. 129, 130, 3 TEXT-FIG., SEPTEMBER 1956

THE TRILOBITE FAMILY ISOCOLIDAE

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ABSTRACT—Type material of the three Middle and Upper Ordovician genera (*Isocolus*, *Cyphoniscus*, *Holdenia*) composing this family is described and figured. The opisthoparian facial suture, eye lobe, and free cheeks (but not doublure or hypostome) of *Isocolus* are clearly revealed, and eye lobe lacks eye facets. *Cyphoniscus* and *Holdenia* have similar sutures, eye lobe small or absent. Each of these trilobites, apparently lacking functional eyes, is of small size, has few thoracic segments, and occurs in a pure limestone reef facies in a limited locale. *Pradesia* is doubtfully placed here, and occurs in a Lower Ordovician clastic facies.

INTRODUCTION

IN THE following pages new figures and notes are given on three species of trilobites, based on an examination of type material. These species, each the type of a separate genus, are considered to belong to a distinct family. They are of especial interest because of their small size and unusual occurrence. *Isocolus sjögreni* comes from several localities in the Boda limestone (Upper Ordovician) of the Lake Siljan district, Dalarne, Sweden. The Boda limestone is a reef facies—lenticular masses of extremely pure, unbedded, white limestone occurring in a bedded series of shales and limestones (Warburg, 1925, p. 411–425; Thorslund, 1936). The fossils occur, sometimes in great numbers, in small patches in the otherwise unfossiliferous reef mass. In the small fragments containing *I. sjögreni* that I have seen, this trilobite is abundant. *Cyphoniscus socialis* comes from the pink-white Upper Ordovician limestones of the Chair of Kildare, Eire, and the Keisley limestone of northern England. Whether or not the former is a reef limestone is uncertain, but as the photographs (Pl. 130, fig. 7–9) show, the limestone is in places crowded with partly disarticulated exoskeletons of this one species. The Keisley limestone may be in part a reef deposit, and particular species occur in abundance in patches (Rhodes, 1955, p. 17–18). Exoskeletal parts of *Holdenia typa* crowd the fragments of the Middle Ordovician Effna reef limestone in which it occurs (Pl. 130, fig. 15). Thus all three of these small trilobites are found in a pure limestone reef facies, and each appears to have a restricted geographical and geological range.

The re-examination has shown clearly the course of the facial suture in *Isocolus sjögreni*, the form of the free cheek, the absence of facets on that part of the "eye lobe" outside the suture (Text-fig. 1), but has not revealed the doublure or hypostome. The cranidium of *Holdenia typa* has a sutural boundary (Text-fig. 3) like that of *Isocolus*, but there is no palpebral lobe or eye ridge. In *Cyphoniscus socialis* (Text-fig. 2) there is an "eye lobe" and a raised line running back from it follows a similar course to that of the posterior branch of the suture in *Isocolus* and *Holdenia*. Thus these three trilobites seem to have lacked functional eyes but to have possessed an opisthoparian suture, the anterior branches of which were confluent. Whether or not median or connective sutures were present is unknown. Other characters in common are the small size, form of the cephalon, the six or seven thoracic segments, and shape of pygidium. Hupé (1955, p. 148–149) suggested that *Pradesia martyi* Thoral may be an isocolid, but it is a far older (Lower Ordovician) species than the others, and occurs in a clastic facies. Hupé (1955, p. 147–148) also expressed the opinion that the Isocolidae were very like the Upper Cambrian genera he included in the Raymondinidae. This suggestion does not appeal to me, and I am unable to indicate to what Upper Cambrian or Ordovician family or families the Isocolidae may be related.

I am indebted to Dr. H. Mutvei, Palaeozoological Department, Swedish Museum of Natural History (RS), for lending me Angelin's types and other material of *Isocolus sjögreni;* to Dr. V. Jaanusson, Paleontological Institute, Uppsala, Sweden

(PU), for lending me additional material of *I. sjögreni* and for supplying information; to Dr. C. J. Stubblefield, Geological Survey and Museum, London (GSM), for allowing me to study the type material of *Cyphoniscus socialis*, and to Mr. W. H. C. Ramsbottom, of the same institution, for help in making the photographs; to Dr. G. Arthur Cooper, U. S. National Museum, Washington, D.C. (USNM) for permitting me to study the original material of *Holdenia typa*. Initials in brackets are used subsequently to indicate the whereabouts of particular specimens. Mrs. M. Kay and Mrs. Stanley J. Olsen have made the enlargements from my negatives, and Miss Pat Washer made the drawings.

SYSTEMATIC PALEONTOLOGY

Family ISOCOLIDAE Angelin, 1854

Diagnosis.—Entire exoskeleton of *Isocolus* and *Cyphoniscus* less than 1 cm. in length, that of *Holdenia* almost 2 cm. in length. Convex cephalon, glabella ovate, outlined by deep axial and pre-glabellar furrows, greatest width at, or in front of, mid-length, deep occipital furrow, up to three pairs of lateral glabellar furrows may be present. Cheeks and frontal area confluent, descending vertically distally, posterior and lateral borders defined by furrows, gently convex, may be long genal spine. Eye lobe, if present, gently convex, situated on antero-lateral part of the cheek adjacent to axial furrow, seemingly combined with eye ridge; eye facets absent. Facial sutures opisthoparian, posterior branch curving across distal part of posterior border, anterior branches confluent along margin of frontal area. Anterior cephalic doublure and hypostome unknown. Thorax of six to seven segments, axis about one-third width, small antero-lateral lobes may be present on rings; inner part of pleura horizontal, outer part bent steeply down, deep pleural furrow. Pygidium with bluntly-terminated axis not reaching posterior margin, one to three rings, convex pleural regions crossed by one or more pleural furrows. External surface with raised, anastomosing lines running sub-parallel to margins, or in Bertillon pattern on cranidium, lines absent in furrows.

Geological range.—Middle to Upper Ordovician.

Genus ISOCOLUS Angelin, 1854

Type species: *Isocolus sjögreni* Angelin, 1854

Pl. 129, fig. 1–11; Text-fig. 1

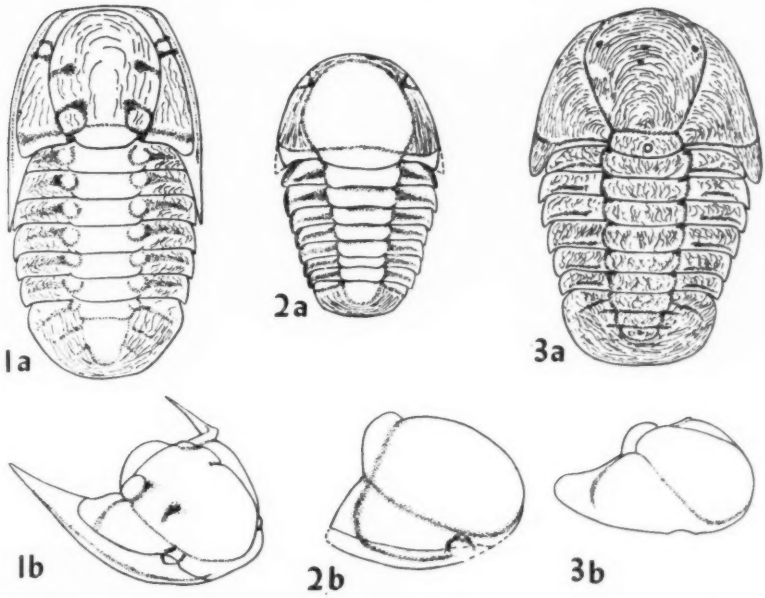
ANGELIN, 1854, p. 58–59, pl. 33, fig. 8.
WARBURG, 1925, p. 331–334, pl. 11, fig. 29.

Lectotype (here selected).—RS 10911, one of Angelin's syntypes, complete exoskeleton in piece of pink, veined limestone, from Boda limestone, Upper Ordovician, Östbjörka, Lake Siljan district, Dalarne, Sweden.

Other Material.—RS 10910, 10912, 10913, the remaining three syntypes of Angelin, including complete exoskeletons, cephala and cranidia, in similar limestone, same locality. RS 10906–10907, cephala collected by Holm from coarse-grained light grey limestone, same horizon at Arfvet, lös sten, Dalarne. RS 10908–10909, complete and incomplete exoskeletons, collected by Törnquist from coarse-grained, pink-white limestone with abundant brachiopods, same horizon, Osmundsberget, Dalarne. PU Ar. 600, original of Warburg, 1925, Pl. 11, fig. 29, an incomplete external mould in a chip of white limestone which also contains two incomplete internal moulds, same horizon, Kallholn, Dalarne.

Discussion.—Removal of the matrix obscuring the margin of the cephalon of three specimens has given additional information about this trilobite, and one of these specimens being a complete exoskeleton, it is selected as lectotype. Warburg's description may thus be supplemented by the new figures and by the following comments:

On the anterolateral slope of the cheek, adjacent to the axial furrow, is a sub-oval gently convex area, the long axis outwardly directed, and defined by a deeper furrow on the posterior than the anterior side (Pl. 129, fig. 4–7). This lobe is the eye lobe, probably combined with the eye ridge, and is crossed on its outer slope by the suture. The small portion of the lobe outside the suture is smooth, and eye facets being thus lacking, it is presumed that the eye was not functional. The posterior branch of the suture curves outward and backward past the outer end of the posterior border furrow and then curves inward over the posterior border to the margin inside the base of the librigenal spine. The anterior branch runs forward and slightly inward to the anterior margin of the



TEXT-FIG. *1–3*—Trilobite family Isocolidae, drawings based on type material. *1*, *Isocolus sjögreni*, *a*, dorsal, *b*, right anterolateral views, ×12½. *2*, *Cyphoniscus socialis*, *a*, dorsal, *b*, right anterolateral views, ×5. *3*, *Holdenia typa*, *a*, dorsal, *b*, right anterolateral views, ×2½.

frontal area, and then along this margin to meet the opposing suture. The course of the suture is clearly shown by the lectotype (Pl. 129, fig. 1,4,7) and another cephalon (Pl. 129, fig. 3,5,6) and the presence of an isolated cranidium (Pl. 129, fig. 8,9,11) suggests that the suture was functional. The anterior cephalic doublure is unknown. The free cheeks are narrow (tr.), steeply sloping, with a narrow, convex lateral border. This border is defined by a shallow border furrow that extends forward from the base of the genal spine to a point just across the anterior branch of the suture, and then dies out. There is thus no anterior border on the steep frontal area. One specimen (Pl. 129, fig. 10), an internal mould, has a concave lateral border, presumably the external mould of the doublure, which thus was apparently narrow and rolled.

External surface bearing fine, raised, anastomosing lines. On cheeks, thoracic pleurae and pleural regions of pygidium, these lines run subparallel to distal margins. On glabella the lines are also subparallel to margins (Bertillon pattern), but on remainder of axis their course is uncertain.

The only record of this genus outside Dalarne, Sweden, of which I am aware is that by Weber (1948, p. 46–47, pl. 7, fig. 28a,b), and it is uncertain whether or not the fragment compared to the type species really belongs there.

The course of the facial suture in *Isocolus* and *Holdenia* is exceedingly similar, but the latter has a differently shaped glabella and lacks the deep lateral furrows and eye lobe. *Cyphoniscus* also has a differently shaped glabella, and lacks lateral furrows, but the eye lobe is present and, seemingly, the posterior branch of the suture has a similar course.

Genus CYPHONISCUS Salter, 1853

Type species: *Cyphoniscus socialis* Salter, 1853

Pl. 130, fig. 1–9,11,12; Text-fig. 2

SALTER, 1853, p. 1–4, pl. 9, fig. 1–5.
REED, 1896, p. 410–411.
WARBURG, 1925, p. 333.

Lectotype (here selected).—GSM 35535, original of Salter, 1853, pl. 9, fig. 1, incomplete cephalon and seven thoracic segments, preserved (with exoskeletal parts of other individuals) in a small piece of pinkish limestone from the Chair of Kildare, southwest of Dublin, Eire. These limestones are

of Upper Ordovician age (Reynolds & Gardiner, 1896; Harper, 1949, p. 58).

Other Material.—GSM 35534 (original of Salter's fig. 2), 35542 and 35543, counterparts (original of Salter's fig. 3), 35533 (possibly the original of Salter's fig. 4), 35530 (originals of Salter's fig. 5, and possibly 6), and an unnumbered piece of limestone containing several specimens, one showing cephalon, complete number of thoracic segments, and pygidium. All from same locality and horizon.

Discussion.—New figures are given here, and the following comments may be made on Salter's description:

The steeply sloping cheeks are confluent anteriorly with the narrow (sag.), steep, preglabellar field. The posterior border is narrow (exs.) proximally, widening outward as the deep border furrow curves forward. On the lectotype (Pl. 130, fig. 1–5) the border furrow extends forward to a point about one-third of the cephalic length from the anterior margin, and defines a convex lateral border. In front of this point, and along the margin of the preglabellar field, no cephalic border is preserved (Pl. 130, fig. 3). Opposite about where the lateral border becomes indistinct there is a low, raised, subcircular region on the cheek, extending from the axial furrow out to the vaguely-defined margin (best seen on the right side of the lectotype, Pl. 130, fig. 1,3). This raised area is probably the eye lobe combined with the eye ridge. A faint raised line runs back from it, across the cheek to the border furrow at the genal angle, and almost directly back across the border (Pl. 130, fig. 2). It is probably this line that Salter interpreted as the posterior branch of the facial suture. He evidently also considered that, in the lectotype, the confluent anterior branches bounded the anterior part of the cheek and the preglabellar field. In the light of what we now know of the course of the facial sutures in *Isocolus sjögreni* this interpretation seems reasonable, and is indicated in Text-fig. 2. In none of the other specimens is the lateral area of the cheek as well preserved as in the lectotype, though in many (e.g., Pl. 130, fig. 6,7,9) the cheek ends laterally (i.e., is broken or concealed) approximately along the line of the posterior branch of the suture. The genal angle of the cheek is preserved only on the left side of the lectotype (Pl. 130, fig. 2), but is partly concealed. It seems as if a genal spine may be lacking, but more evidence is needed.

Pl. 130, fig. 11, shows the only specimen in the type material revealing the complete thorax of seven segments. The best specimen of the pygidium (Pl. 130, fig. 12) is that used by Salter for his pl. 9, fig. 5. On the external surface of the pleural regions of the pygidium and thorax, and of the cheeks, cephalic borders and preglabellar field, are fine, anastomosing, raised lines running subparallel to the margins. On some specimens there are tiny pits between the raised lines. The external surface of the axial region seems generally to be smooth, but on one cranidium there are raised lines on the glabella, subparallel to the lateral and anterior margins and anastomosing.

Distinctive of *Cyphoniscus* is the subcircular outline of the glabella, the con-

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EXPLANATION OF PLATE 129

FIG. *1–11*—*Isocolus sjögreni* Angelin, 1854. Boda limestone (Upper Ordovician), Lake Siljan district, Sweden. *1,4,7*, lectotype, complete exoskeleton, dorsal stereograph (right hand figure of pair not numbered), ×10; right anterolateral and right lateral views, ×15; RS 10911, Östbjörka. *2*, cast from external mould, original of Warburg, 1925, pl. 11, fig. 29, dorsal view, ×10; PU Ar. 600, Kallholn. *3,5,6*, cephalon and two thoracic segments, anterior view, ×15; right anterolateral view, ×20; left anterolateral view, ×10; RS 10913, Östbjörka. *8,9,11*, cranidium, left anterolateral view, ×15; anterior view, ×10; right anterolateral view, ×15; RS 10907, Arfvet lös sten. *10*, cephalon and three thoracic segments, right anterolateral view, ×15; PU Ar 600, Kallholn.

12–17—*Holdenia typa* Cooper, 1953. Effna limestone (Middle Ordovician), 2 miles southwest of Saltville, Va.; USNM. *12,15,16*, paratype cranidium, original of Cooper, 1953, pl. 2, fig. 13, right anterolateral view, ×6; dorsal view, ×4; left anterolateral view, ×6; no. 116427. *13*, incomplete cranidium, dorsal view, ×6. *14*, cranidium, left anterolateral view, ×6. *17*, incomplete cranidium, dorsal view, ×4.

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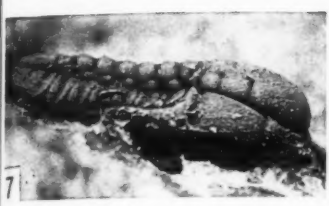
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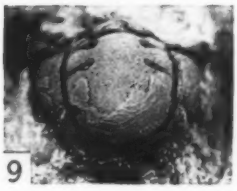
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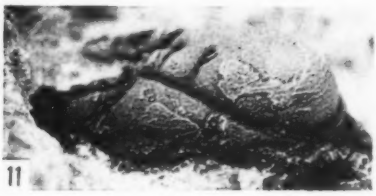
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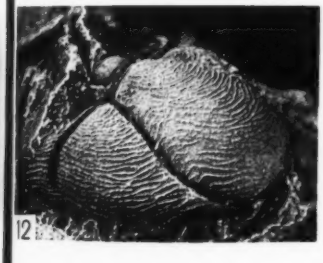
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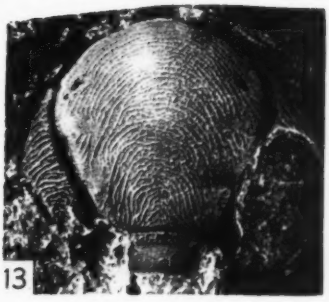
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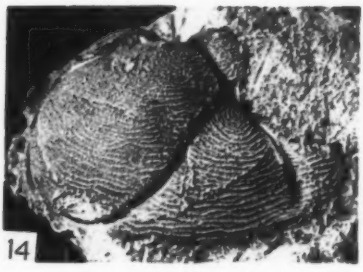
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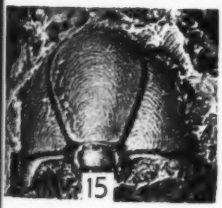
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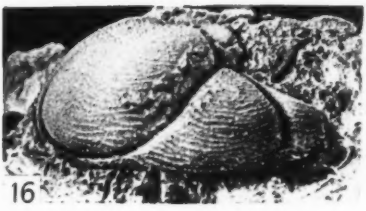
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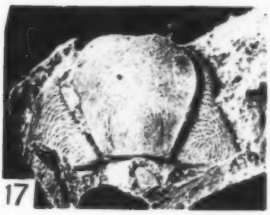
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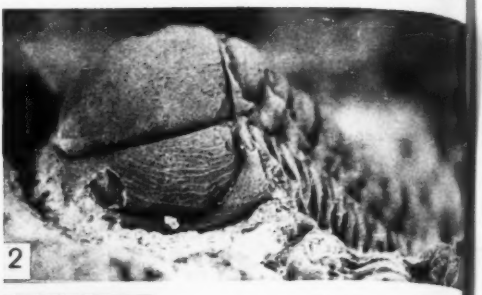
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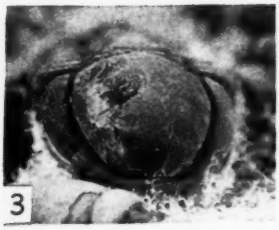
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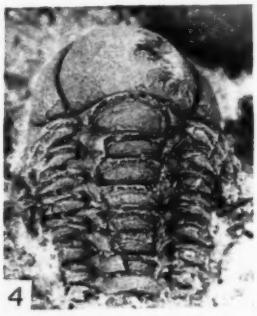
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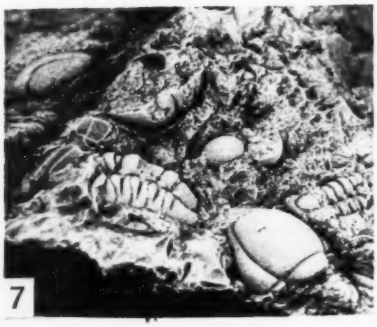
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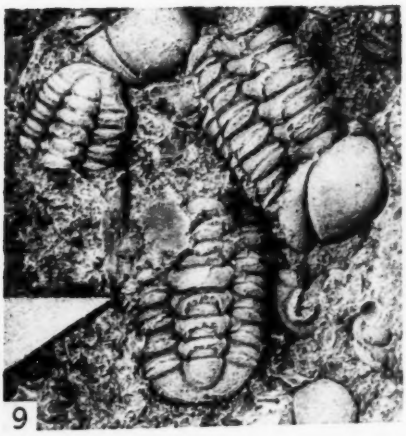
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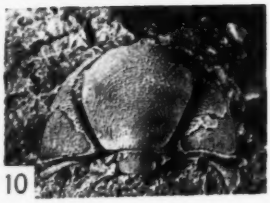
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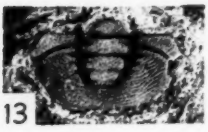
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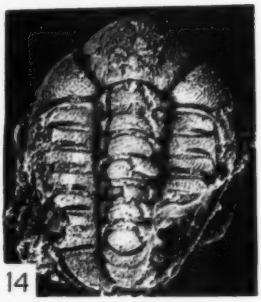
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fluence of posterior and lateral border furrows, and the apparent lack of a genal spine.

Genus HOLDENIA Cooper, 1953

Type species: *Holdenia typa* Cooper, 1953

Pl. 129, fig. 12–17; Pl. 130, fig. 10,13–15; Text-fig. 3

COOPER, 1953, p. 9–10, pl. 2, fig. 11–14.

Holotype.—USNM 4685, original of Cooper, 1953, pl. 2, fig. 11, incomplete exoskeleton, from Middle Ordovician, Effna limestone, Porterfield quarry of the Mathieson Alkali Works, two miles southwest of Saltville, Smyth Co., Virginia.

Other Material.—Paratypes, USNM 116427a–c, two cranidia and a pygidium; many other cranidia, all from same horizon and locality.

Discussion.—Examination of the above material has revealed some features not mentioned in the original description. Three pairs of lateral glabellar furrows are present, situated equidistantly from each other and the occipital furrow, the anterior being in front of the widest part of the glabella. The median and posterior furrows are represented by faintly depressed, smooth, sub-oval areas which extend inward a short distance from the axial furrow. The amount of the depression in the external surface varies (compare and contrast Pl. 129, fig. 12–14, 17; Pl. 130, fig. 10), and there is a corresponding raised area on the inner surface. The anterior furrow is in the form of a subcircular smooth area, situated a short distance in from the axial furrow, and may be faintly, or not at all, depressed (Pl. 129, fig. 12; Pl. 130, fig. 10), or indented to form a shallow pit (Pl. 129, fig. 13,14,17). A small median occipital tubercle is developed (Pl. 129, fig. 14). The raised, anastomosing lines on the external surface of the glabella (except in the furrows) and cheeks form a typical Bertillon pattern—sub-concentric on the glabella about the mid-point of the occipital furrow, subconcentric on the cheek about the inner, posterior corner.

The anterior and lateral margins of many cranidia are like those shown in Pl. 129, fig. 12,14,16; Pl. 130, fig. 15—a distinct, smoothly curving line with a slight indentation antero-laterally, opposite the most anterior part of the glabella. Postero-laterally is a short, broad (tr.) backward prolongation of the border, the outer margin continuing the curve of the cheek margin, the distal margin a semi-circular curve. Since the position and outline of the margin of these cranidia is so exactly alike, I conclude that this margin is a sutural boundary. The antero-lateral indentation presumbably indicates the position of the eye lobe, but there is no inflation of the cheek inside this indentation, suggestive of palpebral lobe or eye ridge. The course of the sutures is exceedingly like that in *Isocolus sjögreni*. Free cheeks were not found in the material.

Axial rings of thorax (Pl. 130, fig. 14) with antero-lateral inflation, articulating half-ring long. Pleural furrow close to posterior margin of pleura, and deepening toward fulcrum. Pygidium (Pl. 130, fig. 13) with

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EXPLANATION OF PLATE 130

FIG. *1–9,11,12*—*Cyphoniscus socialis* Salter, 1853. Upper Ordovician limestone, Chair of Kildare, Eire. *1–5*, lectotype, cranidium and seven thoracic segments, original of Salter, 1853, pl. 9, fig. 1; *1*, right lateral view, ×6; *2*, left lateral view, ×9; *3*, anterior view, ×6; *4*, dorsal view of thorax, ×6; *5*, dorsal view of cephalon, ×4½; GSM 35535. *6*, cranidium, (?) original of Salter, 1853, pl. 9, fig. 6, right anterolateral view, ×4; GSM 35530. *7*, cranidium, (?) original of Salter, 1853, pl. 9, fig. 4, lateral view, ×4; GSM 35533. *8*, cranidium and seven thoracic segments, original of Salter, 1853, pl. 9, fig. 3, dorsal view, ×4; GSM 35543. *9*, thorax and pygidium, (?) original of Salter, 1853, pl. 9, fig. 2, dorsal view, ×6; GSM 35534. *11*, almost complete exoskeleton, dorsal view, showing seven thoracic segments, ×6; GSM. *12*, pygidium, original of Salter, 1853, pl. 9, fig. 5, dorsal view, ×4; GSM 35530.

10,13–15—*Holdenia typa* Cooper, 1953. Effna limestone (Middle Ordovician), 2 miles southwest of Saltville, Va. USNM. *10*, cranidium, dorsal view, ×4. *13*, paratype pygidium, original of Cooper, 1953, pl. 2, fig. 14, dorsal view, ×4; no. 116427. *14*, holotype, incomplete exoskeleton, original of Cooper, 1953, pl. 2, fig. 11, dorsal view of thorax, ×4; no. 4685. *15*, cranidium, right anterolateral view, ×6.

deep first pleural furrow extending out close to margin, second pleural furrow faint and not extending as far. Inner part of first and second interpleural grooves present, the first the more distinct. External surface of thoracic and pygidial pleural regions bearing anastomosing raised lines running subparallel to distal margins. On axis, as on occipital ring, lines irregularly longitudinal.

The outline of the glabella, widest just behind the third (anterior) lateral lobes, the lack of palpebral lobe and eye ridge, and the position of the thoracic pleural furrows, combine to distinguish *Holdenia* from either *Isocolus* or *Cyphoniscus*.

?Family ISOCOLIDAE Angelin, 1854
Genus PRADESIA Thoral, 1935

Type species: *Pradesia martyi* Thoral, 1935

THORAL, 1935, p. 311–315, pl. 21, fig. 1.
HUPÉ, 1955, p. 148–149.

Discussion.—Based on a single specimen, preserved as an internal mould, in a siliceous nodule from the Lower Ordovician of southern France. Outline and form of glabella resembles that of *Holdenia*, but anterolateral lobes of occipital rings, deep basal, and faint fourth, lateral glabellar furrows, are distinctive. Free cheeks and course of facial sutures unknown, except that the rostral suture runs along the junction between preglabellar field and broad anterior doublure, and latter shows no median suture. The thorax and pygidium of *Pradesia* are more like those of *Isocolus* than those of *Cyphoniscus* or *Holdenia*. Hupé suggested that *Pradesia* may be an isocolid. If this is accepted, *Pradesia* would be by far the oldest isocolid, and it occurs in a clastic rather than a limestone facies. Inclusion of *Pradesia* would involve minor modifications of the family diagnosis given above.

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MANUSCRIPT RECEIVED FEBRUARY 23, 1956

JOURNAL OF PALEONTOLOGY, VOL. 39, NO. 5, P. 1199, SEPTEMBER 1956

PALEONTOLOGICAL NOTE

PHACOPID ONTOGENIES

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In the course of his interesting article on the phacopid affinities of Beecher's supposed odontopleurid protaspis, Professor H. B. Whittington (1956) criticizes my interpretation (1952) of the composite nature of the third (anterior) glabellar furrows of *Dalmanitina*. My views on this and related topics are being developed in some detail elsewhere, but perhaps I may comment briefly here on the points that Whittington raises.

In what follows I shall refer mainly to my 1952 Text-fig. 1 of *D. olini* Temple; and I shall assume that it is agreed that the adult glabellar outline is *ahcdf* etc., and that the adult third furrow is *gbd* with the locus *d* of the anterior pit (and in *D. socialis*, as Whittington has shown, with the pit itself) at its distal end.

Whittington suggests:

(1) that the primary glabellar outline in Beecher's phacopid metaprotaspis and in that of *D. socialis* (Barrande) is *ahcde* etc.;

(2) that *bd* of the adult third furrow does not represent what was originally part of the axial furrow in the protaspis, but is a later "extension outward" (and presumably also forward) of the third furrow.

In reply it may be remarked:

(1) that in the metaprotaspis of *D. olini* the glabellar outline appears to be *ahbde*, not *ahcde*, and even if this were not so the striking similarity of this outline to those of the otherwise very similar protaspides of non-phacopid proparian forms (compare my 1952, pl. 10, fig. 6 with Ross, 1951, pl. 82, and with Whittington & Evitt, 1954, pl. 15, fig. 1) would suggest *ahbde* as the primary outline. In *D. olini* it is later superseded by *ahcde*, and from Whittington's descriptions one must conclude that in the metaprotaspides of *D. socialis* and of Beecher's form a similar change has already taken place;

(2) if *bd* in the adult is not the remnant of part of the axial furrow in the protaspis, it must be a secondary oblique furrow developed in the same position as the old axial furrow (if we may now assume a primary glabellar outline *ahbde*): this is surely a remarkable coincidence, and seems to be an unnecessary hypothesis.

My interpretation of the third furrows of *Dalmanitina* was based originally on those stages of *D. olini* in which one can see happening the changes that I described (1952, pl. 9, fig. 3–6). Whittington does not offer a re-interpretation of these stages in the light of his criticism, and I do not consider that his own observations on *D. socialis* and on Beecher's protaspis conflict with mine on *D. olini*, or with the inferences I drew from them.

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MANUSCRIPT RECEIVED MAY 1, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1200–1204, PL. 131, 1 TEXT-FIG., SEPTEMBER 1956

BEECHER'S LICHID PROTASPIS AND *ACANTHOPYGE CONSANGUINEA* (TRILOBITA)

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ABSTRACT—New photographs and drawings are given of the lichid protaspis described by Beecher in 1893. Eye lobe is prominent and facial sutures may be seen. It is not certain that, as Beecher believed, this is the protaspis of *Acanthopyge consanguinea*. The type and additional well-preserved material of this species is described.

INTRODUCTION

IN 1893 Beecher described two trilobite protaspides. A new account of one of them has recently been given (Whittington, 1956a), the other is dealt with in the following pages. Beecher briefly characterised this protaspis, gave three drawings, and referred it to "*Phaëthonides* sp." (1893, p. 144–145, pl. 2, fig. 8–10). Two years later (Beecher, 1895, p. 173, pl. 9, fig. 4) he identified it as *Arges consanguineus* Clarke, and a new dorsal view was drawn. The latter has been reproduced and commented on at intervals since (Størmer, 1942, p. 93, pl. 1, fig. 40; Hupé, 1955, p. 229, fig. 203,2). Re-examination of the single original specimen has yielded new information, and in particular has shown that the eye lobes are prominent, and that the facial sutures can be traced (Text-fig. 1), and are not absent as Beecher claimed.

The first question that arises is: Is this a lichid protaspis? I believe that it is, because of its great similarity to protaspides known to be those of lichids in undescribed collections of silicified Middle Ordovician trilobites made by W. R. Evitt and me. The second question—To what species may this protaspis be referred?—cannot be answered with any certainty. Beecher, from the same material which yielded the protaspis, obtained silicified exoskeletal parts of a lichid identical with Clarke's species *A. consanguineus*. He therefore regarded the protaspis as belonging to this species. Beecher's material of *Acanthopyge consanguinea* is here also described, together with Clarke's type material. The smallest cranidium, however, is a holaspis, so that the development cannot be traced step by step through the meraspid period. The holaspid cephalon of *A. consanguinea* (Pl. 131, fig. 7–13,20) is in certain features quite unlike that of the protaspis (Pl. 131, fig. 1,3–5), which has a parallel-sided glabella, the cheeks widest in front of the genal spine, and the latter situated at the posterior corner of the free cheek. In both cephala, however, there is a depressed region in front of the occipital ring, and the inflated part of the cheek of the protaspis, between eye lobe and glabella, is in the position occupied by the bicomposite lobe of the holaspis. The protopygidium of the protaspis is similar to that of the holaspis (Pl. 131, fig. 14,17). Lacking a developmental series of any lichid, let alone of this particular species, I hesitate to identify this protaspis. Further, there are two other species of lichids that occur in these same rocks (Hall, 1859, p. 364–368, pl. 77,78), and the protaspis might be of one of these.

The lichid protaspis has some similarity to those of odontopleurids (Whittington, 1956b) in outline, convexity, and spinosity, but is twice the size of any of these odontopleurid protaspides. Other striking differences are the deep axial furrows in the lichid, the broader anterior and antero-lateral borders, lack of fixigenal spines, and shorter protopygidial axis (not reaching to posterior margin of protopygidium). This dissimilarity between protaspides is one of the reasons that leads me to regard these families as seemingly not closely related to each other (Whittington, 1954, p. 196, 198).

I am indebted to Mr. Clinton R. Kilfoyle, New York State Museum, Albany (NYSM) for the loan of Clarke's type material; to Dr. Karl M. Waagé, Peabody Museum of Natural History, Yale University (YPM) for the loan of Beecher's specimens, and to Professor W. R. Evitt and Mr. R. P. Tripp

for advice. Initials in brackets are used subsequently in referring to particular specimens.

SYSTEMATIC PALEONTOLOGY

Family LICHIDAE Corda, 1847

Lichid protaspis

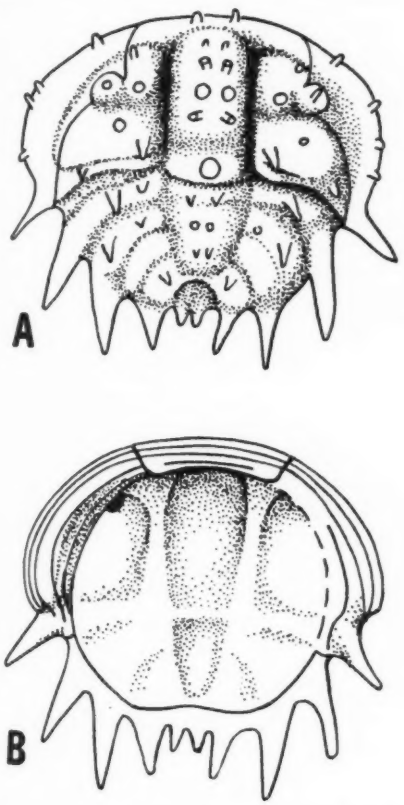
Pl. 131, fig. 1–6; Text-fig. 1 a,b

Phaëthonides sp., BEECHER, 1893, p. 144–145, pl. 2, fig. 8–10.

Arges consanguineus, BEECHER, 1895, p. 173, pl. 9, fig. 4.

Material.—One silicified protaspis, YPM 6610, from the Lower Devonian, New Scotland limestone, Indian Ladder, Albany Co., N. Y., collected and prepared by C. E. Beecher.

Description.—Shield of length (sag.) 0.94 mm., maximum width (in transverse line passing immediately in front of occipital ring) 1.25 mm., length (sag.) of cephalic portion of shield 0.54 mm., quite strongly convex except for flattened lateral parts of cheeks, axis well marked by deep furrows. Glabella subparallel-sided, convex, short (sag.) occipital ring with median spine, in front of this a portion of glabella (of same length (sag.) as occipital ring) depressed, then anterior part strongly convex, sloping almost vertically anteriorly, 4 pairs of spines, the anterior pair low down on the steep slope. Inner part of cheek quite convex, distinct posterior border runs out transversely, distally curving back into base of genal spine. Faintly convex, narrow lateral borders continued in front of glabella by anterior border, which forms the short (sag.) preglabellar field. Prominent eye lobe situated on antero-lateral slope of inner, convex, part of cheek. The manner in which the suture curves over the outer surface of the eye lobe is shown in Pl. 131, fig. 4,5, and tiny facets, arranged in diagonal lines, may also be seen. Branches of suture difficult to discern, but appear to run as shown in Text-fig. 1, the rostral suture being along the anterior margin of the preglabellar field. Rostrum with posterior margin (hypostomal suture) a curve gently concave posteriorly. Beneath lateral part of cheek doublure becomes broad, but inner edge broken off on left side, and obscure on right. The larger spines on the fixed cheek are shown in Text-fig. 1, and the cheek is inflated around the base of the spine situated between palpebral lobe and axial furrows.



TEXT-FIG. 1—Lichid protaspis, original of Beecher (1893, 1895) *a*, dorsal, *b*, ventral view. Only larger spines of external surface shown. Approx. ×40.

The axis of the protopygidium, defined by deep axial furrows, is rapidly reduced in height posteriorly and reaches only about two-thirds of the way to the margin; it bears three pairs of spines. The gently convex pleural regions bear four pairs of marginal spines, the posterior pair tiny and close together behind the axis. The pleural regions are subdivided as shown in Text-fig. 1: three slightly convex posterior pleural bands curve out from opposite each pair of axial spines to the base of the first three marginal spines, and each bears a stout spine on the upper surface of the distal portion. The anterior pleural bands are depressed, and that of the third segment wider than those in front. Behind the axis the pleural regions are depressed.

The specimen has many fragments clinging to it, particularly to the inner surface, so that some details of both surfaces are obscured. The larger spines of the external surface are clearly seen (Text-fig. 1) but there are also scattered smaller spines. These latter have not been shown on Text-fig. 1, except for those on the lateral and anterior cephalic borders. The form of the doublure is visible, and the characteristic strong terrace lines on the cephalic portion.

Genus ACANTHOPYGE Corda, 1847
(=*Euarges* Gürich, 1901, objective synonym)

Type species: *Lichas haueri* Barrande, 1846=*Acanthopyge leuchtenbergii* Corda, 1847; designated Reed, 1902, p. 60.

ACANTHOPYGE CONSANGUINEA (Clarke, 1894)
Pl. 131, fig. 7–20,23; ? fig. 21,22

Arges consanguineus, CLARKE, 1894, p. 746, footnote, fig. 65.

Holotype.—NYSM 4530, an incomplete cranidium, original of Clarke, 1894, fig. 65, from the Lower Devonian, New Scotland limestone, Feurabush, Albany Co., N. Y. Clarke gives the locality as "near Clarksville." The latter is on the Helderberg escarpment southwest of Albany, Feurabush at the foot of this escarpment, the outcrop of the New Scotland limestone being about mid-way between these towns.

Other material.—Isolated hypostome, included in same lot as holotype. YPM 6561, 10 cranidia, 4 free cheeks, 6 pygidia, all from the same beds at Indian Ladder, Albany Co., N. Y., collected and prepared by C. E. Beecher.

Description.—Holotype cranidium of length (sag.) 4.2 mm.; another cranidium (original of Pl. 131, fig. 10,11,13,20) of length (sag.) 3.5 mm., width at posterior border 5.6 mm. Cephalon of height half maximum width, which is at posterior border, strongly convex glabella and inner parts of cheeks sloping steeply down to nearly horizontal borders. Occipital ring strongly convex (tr.), widest (sag.) in mid-line, the posterior margin almost straight, the anterior curved back so that the ring tapers to a blunt point at the axial furrow. Occipital furrow shallow. Frontomedian lobe gently convex transversely, at its base about two-thirds the width of occipital ring, minimum width at about half the length, then widening rapidly to maximum width (greater than length) in front of bicomposite lateral lobes; at base of median lobe a depressed zone, extremely narrow (sag.) in the midline, widening (exs.) distally. Bicomposite lateral lobe moderately convex, defined on all sides by shallow furrows. Shallow anterior pit in junction of furrows at lateral extremity of frontal lobe. Cheek strongly inflated at inner posterior corner (between bicomposite lateral lobe and distal part of occipital ring), descending vertically to posterior border, steeply laterally; eye lobe situated on this steep lateral slope in line with posterior part of bicomposite lobe, strongly convex. Low eye ridge runs forward and inward from palpebral lobe to reach axial furrow opposite widest part of bicomposite lobe. Posterior border widens rapidly outward and swings forward distally to run, at an acute angle to the exsagittal line, into the base of the genal spine. Latter opposite eye lobe, spine broad, flat, curving back to blunt point. Lateral part of cheek outside eye lobe small, triangular in outline, the broad border enclosing a small inner area and running forward and inward at about 45° to merge with the narrow (sag. and exs.) anterior border. Both branches of facial suture run along sutural ridges, the anterior straight forward and inward to the margin, the posterior downward and outward in an 'S' curve over the border and doublure. Rostral suture runs along anterior margin, connective suture downward and inward, short. Interior views of cranidium and free cheek (Pl. 131, fig. 12,23) show that the doublure extends from the distal part of the posterior border to the connective suture, maximum width between eye lobe and base of genal spine, where it is bent up close to dorsal exoskeleton. Furrows bounding glabellar lobes form ridges, and where inner corner of bicomposite lobe abuts against distal angle of depressed region at base of median lobe, there is a domed projection. The anterior boss, best seen on the left side of Pl. 131, fig. 23, has a deep pit in the anterior slope.

Hypostome (Pl. 131, fig. 21,22) of length (sag.) 4.1 mm., width at shoulders 5.9 mm. Middle body transversely ovate, short

wide middle furrows, adjacent to inner end of which the outer part of posterior lobe of middle body is gently inflated to form the macula. No anterior border, lateral and posterior borders wide. Small anterior wing directed upward and outward, behind it the shallow lateral notch and then the projecting, ridged shoulder. Shallow median notch in posterior border, median part of this border gently inflated.

External surface of cephalon bearing scattered thick, blunt spines, some of the largest of which are paired—e.g., the three on the median glabellar lobe (including that on the depressed basal region), one on the posterior part of the bicomposite lobe, one on the fixed cheek inside and behind the eye lobe. There is a small median, as well as large paired, occipital spines. Between the spines are granules. Conspicuous terrace lines on doublure of free cheek and outer and under sides of genal spine. The large spines on the external surface appear as deep pits on the inner surface, notably the pair on the depressed region of the median glabellar lobe (Pl. 131, fig. 23). Middle body of hypostome and lateral borders pitted, near margin of border ridges between pits run together to form raised lines.

Thoracic segments unknown.

Largest, most complete pygidium (Pl. 131, fig. 14–16) of length (sag.) 2.9 mm., width at anterior margin 4.1 mm. Prominent axis extends more than two-thirds length, continued to margin by low post-axial ridge. Short (sag.) first ring clearly demarcated by articulating furrow and steep posterior edge, faint furrow may outline second ring. Postero-median part of axis swollen and bearing group of spines, of which a median is most prominent. Horizontal pleural regions bear three pairs of blade-like border spines, upturned distally. First two pleurae clearly defined by convex posterior band which slopes vertically down to interpleural groove, and with pleural furrows. Posterior band runs into posterior side of base of border spine. Remainder of pleural regions undivided, third pair border spines close together at tip. Doublure widest posteriorly, bent up so that inner edge is close to dorsal exoskeleton. External surface with large paired spines on axial rings and posterior pleural bands, smaller spines subsymmetrically arranged on axis and pleural regions (including upper surface of border spines), granules between them. On doublure terrace lines sub-parallel to margin, on under surface of border spines the terrace lines in backwardly-directed "V" form.

One incomplete small pygidium (Pl. 131, fig. 19) is probably an early holaspid, the three border spines being about equally spaced from each other.

Discussion.—The cephalon of *Acanthopyge consanguinea* displays the morphological features characterising that of the type species *A. haueri* (Barrande, 1852, p. 604–606, pl. 28, fig. 38–44). The pygidium of the American species differs from that of the type species in the relatively shorter post-axial portion of the pleural regions, and the less convex posterior pleural bands and post-axial ridge. The hypostome of *A. haueri* has a different outline from the specimen figured here (Pl. 131, fig. 21, 22), and is tuberculate, not pitted, and it may be that the hypostome from Feurabush belongs to a species other than *A. consanguinea.* Species of the *Acanthopyge* group in the late Silurian and Lower and Middle Devonian of Germany and Bohemia have recently been described by Přibyl & Erben (1952), and new genera and subgenera erected on the basis of differences between the pygidia. Pending a forthcoming revision of the lichid trilobite genera by R. P. Tripp these subdivisions are not used here. The *Acanthopyge* group is also known in the Silurian of Britain and the Silurian and Devonian of Australia. A recent description of silicified specimens of a new Middle Devonian species *A. bifida* from southeastern Australia is by Edgell (1955). The cephalon of this species is like that of *A. consanguinea,* but the thick spines on glabella, inner part of fixed cheek, and free cheek are relatively larger, and there is a median occipital spine. The pygidium of *A. bifida* has a relatively much wider axis, and the third pair of border spines are situated at the posterior tip, fused proximally and separated distally. Spines on the external surface are coarser. The hypostome of *A. bifida* differs from that here referred doubtfully to *A. consanguinea* only in details of outline and convexity of various parts, and in that the middle body is tuberculate rather than

pitted. Because of the spinosity of the external surface Edgell compared his species to *Acanthopyge* (*Mephiarges*) *mephisto* (R. & E. Richter, 1918, 1930), but the cephalon of the latter species is seemingly far the more convex, has a wider (tr.) free cheek, and the pedunculate eye lobe bears a large spine. Only the cephalon of *A.* (*M.*) *mephisto* is known, and I consider *A. bifida* Edgell probably more closely allied to the species described here or to some of the species described by Přibyl & Erben. Descriptions of North American Silurian and Devonian lichids are few, so that the distribution of *Acanthopyge* on this continent is unknown.

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MANUSCRIPT RECEIVED FEBRUARY 23, 1956

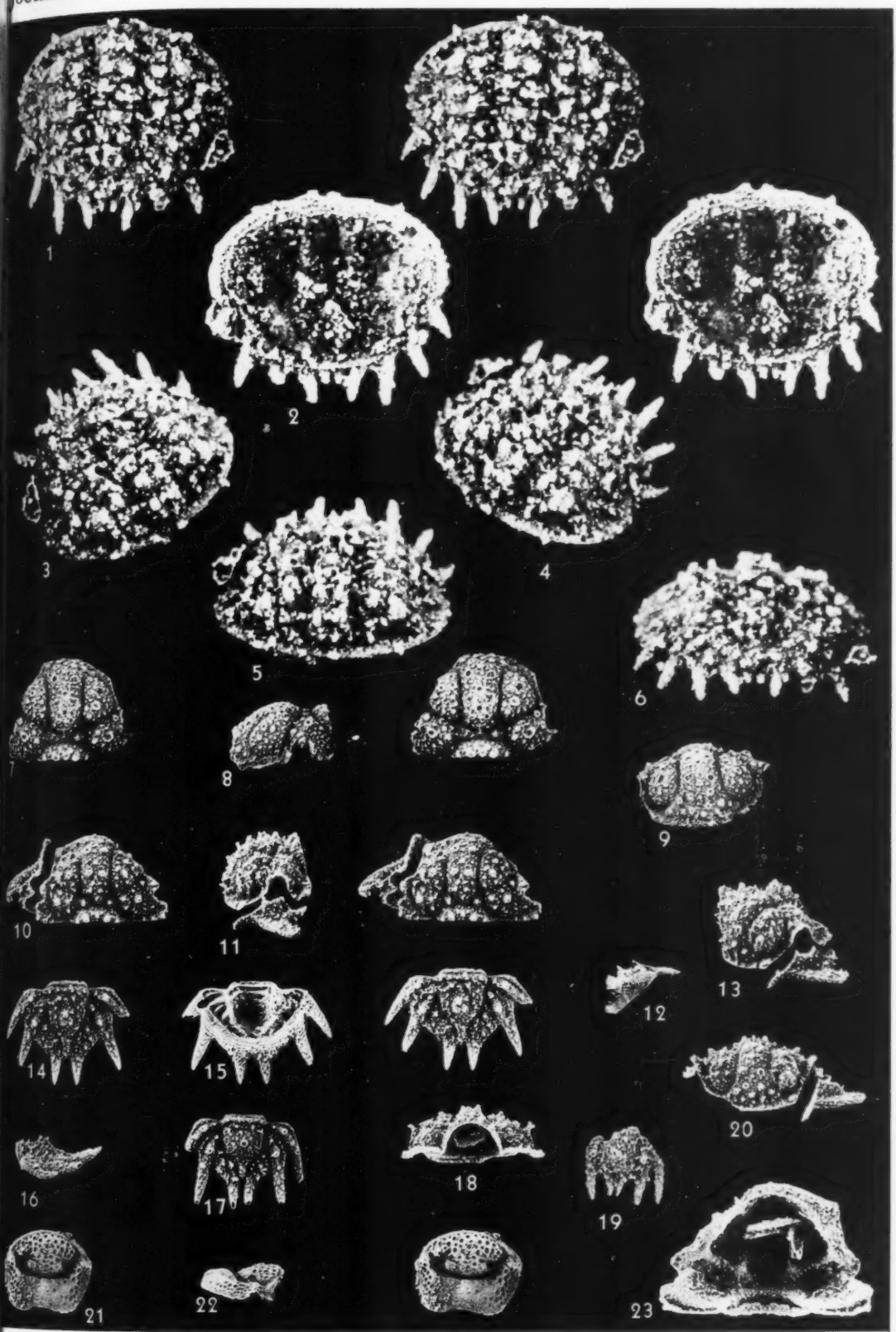
EXPLANATION OF PLATE 131

FIG. *1–6*—Lichid protaspis; *1,2*, dorsal, ventral stereographs, *3–6*, right anterolateral, left anterolateral, anterior, posterior views, ×30. Original of Beecher, 1893, pl. 2, fig. 8–10; 1895, pl. 9, fig. 4. New Scotland limestone, Indian Ladder, Albany Co., N. Y. YPM 6610.

7–20,23—Acanthopyge consanguinea (Clarke, 1894). *7–9*, holotype, incomplete cranidium, dorsal stereograph, left lateral and anterior views, ×4. Original of Clarke, 1894, fig. 65, New Scotland limestone, Feurabush, Albany Co., N. Y. NYSM 4530. *10,11,13,20*, cranidium and free cheek, dorsal stereograph, left lateral, left anterolateral, anterior views, ×4. New Scotland limestone, Indian Ladder, Albany Co., N. Y. YPM 6561a, b. *12*, free cheek, interior view, ×4. Same specimen as in fig. 10,11,13,20. *14–16*, pygidium, dorsal stereograph, ventral and left lateral views, ×4. Same locality as fig. 10, YPM 6561c. *17*, pygidium, dorsal view, ×4. Same locality as fig. 10, YPM 6561d. *18,23*, cranidium, posterior view, ×4, interior view, ×6. Same specimen as in fig. 10,11,13,20. *19*, small holaspid pygidium, dorsal view, ×10. Same locality as fig. 10, YPM 6561e.

21,22—Acanthopyge consanguinea (Clarke, 1894)? Hypostome, exterior stereograph and left lateral view, ×3. In same lot as holotype, NYSM 4530.

Right hand figure of a pair forming a stereograph not numbered.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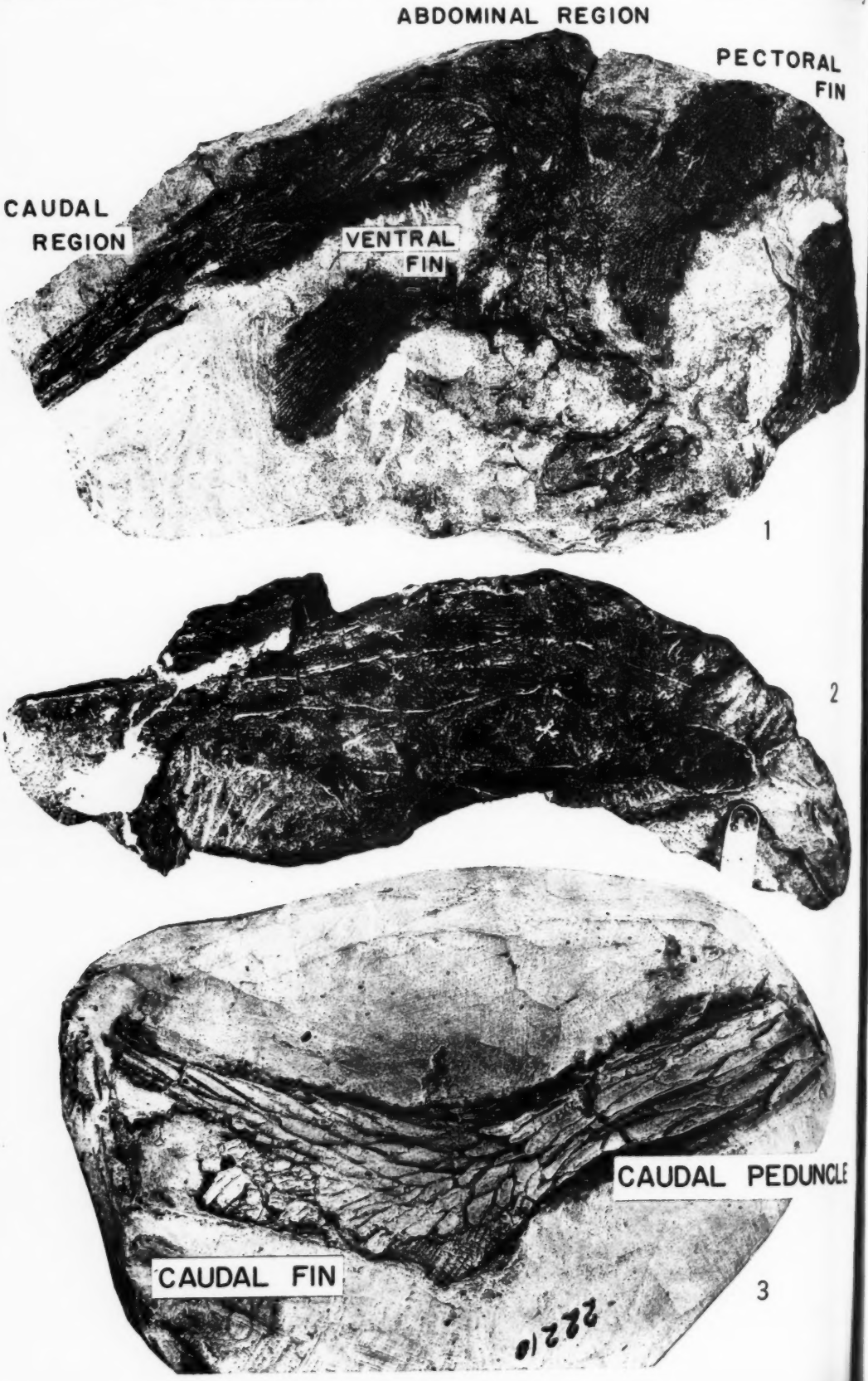
ABDOMINAL REGION
PECTORAL FIN
CAUDAL REGION
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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1205–1208, PL. 132, 1 TEXT-FIG., SEPTEMBER 1956

PROTOSCAPHIRHYNCHUS SQUAMOSUS, A NEW STURGEON FROM THE UPPER CRETACEOUS OF MONTANA

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ABSTRACT—A new species of sturgeon, *Protoscaphirhynchus squamosus*, is described from the Upper Cretaceous Hell Creek beds near Fort Peck, Montana. The species is distinctive in possessing a body covering of scale-like plates, suggesting that external armor is a primitive condition in this group. Its occurrence with a polyodontid fish indicates that if the Polyodontidae are an offshoot of the Acipenseridae, differentiation must have taken place earlier than Upper Cretaceous. Six species of *Acipenser*, ranging from Cretaceous to Miocene, are briefly discussed.

INTRODUCTION AND ACKNOWLEDGMENTS

DURING the Summer of 1938 a group from the University of Michigan Museum of Paleontology consisting of the late Dr. E. C. Case, W. H. Buettner and J. A. Wilson, collected a large duck-bill dinosaur (*Anatosaurus*) from the Hell Creek beds of the Upper Cretaceous approximately 24 miles southeast of Fort Peck, Montana. Associated with the dinosaur were parts of three of four fishes. MacAlpin (1941, 1947) described two of the specimens as *Paleopsephurus wilsoni*, a polyodontid fish. The third fish was tentatively identified as a "Scaphirhynchus-like acipenseroid" (MacAlpin, 1947, p. 168) and reserved for later description. Although the material is far from adequate and no additional specimens have been received, it is felt that the significance of this find in delineating the evolution of the sturgeons warrants publication.

It should be noted that although there is an extensive literature on the Recent sturgeons, comparatively little has been written on the extinct forms, due largely to the lack of material. In addition to the description of this new form and evaluation of its evolutionary significance, a second purpose of this paper is to note the other described fossil sturgeons and to make known some new material of previously described forms. I wish to express my heartiest thanks to Dr. Claude W. Hibbard of the University of Michigan for his many courtesies and aid, as well as for allowing me to describe this form.

SYSTEMATIC PALEONTOLOGY

Order Acipenseriformes

Three families are usually recognized as belonging to the order Acipenseriformes. For example, Berg (1940) divides the Acipenseriformes as follows:

Chondrosteidae—Lower Lias [=Lower Jurassic]-Lower Cretaceous
Acipenseridae—Upper Cretaceous-Recent
Polyodontidae—Upper Cretaceous-Recent

There are a number of good criteria for distinguishing the families but I here wish to point out especially the differences in squamation. Chondrosteidae are naked, Acipenseridae have been characterized as having the squamation largely limited to five rows of scutes on the body, and Polyodontidae are naked or covered with small denticles. The form herein described definitely has the cranial features and body form of the acipenserids but was apparently covered with small scale-like plates.

The last general review of the fossil

EXPLANATION OF PLATE 132

Protoscaphirhynchus squamosus, n. sp.

FIG. *1*—Body and caudal region, ×⅓. The block also contains the impression of two pectoral fins and one pelvic fin of a larger fish, probably of this species.
2—Cranium, ×¾; see Text-fig. 1.
3—Holotype, UMMP 22210, caudal peduncle and heterocercal tail, ×⅓.

Chondrosteidae was by Woodward (1889) and is still the best discussion of the group available. MacAlpin's work (1947) contains a review of the available knowledge on the polyodontids. To my knowledge, no general review of the fossil Acipenseridae has appeared.

Family ACIPENSERIDAE

Although a number of systematic summaries record the appearance of the Acipenseridae as dating from the Upper Cretaceous, Romer (1945, p. 579) indicates as doubtful the records for *Acipenser*. Berg's (1940) Upper Cretaceous record is based upon scutes, but he does not indicate the source of his data. To my knowledge, heretofore a single sturgeon has been described from the Cretaceous.[1]

ACIPENSER ALBERTENSIS Lambe, 1902

Acipenser albertensis LAMBE, 1902, Contr. Canadian Paleont. vol. 3 (quarto), pt. 2, p. 29.

Horizon.—"Mid-Cretaceous"=Upper Cretaceous.

Locality.—Belly River series, Red Deer River, Alberta.

Remarks.—*A. albertensis* is known only from scutes, as is the case with all the other described fossil sturgeons. The records for this species from Wyoming very likely belong to the form described herein, as is suggested by the note contained in Hatcher's report (1905). Although an examination of the scutes upon which Lambe based his *Acipenser albertensis* shows only slight differences from similar plates of the species described herein, it is likely that the forms are specifically, if not generically, distinct. It may be noted that the Cretaceous duckbill dinosaurs of the Red River deposits are specifically different from those of the Hell Creek beds. As the form herein described is based on considerably more material than scutes, the position could be taken that "the great majority of the specific names [in paleontology are] of no value beyond indicating certain specimens or providing for more exact reference" (Case, 1946, p. 325). This difference in the working concept of the species between the paleontologist and the neobiologist is due to the fact that the former necessarily works with the individual specimens, whereas the neobiologist bases his species upon populations.

ACIPENSER TOLIAPICUS Agassiz, 1844

Acipenser toliapicus AGASSIZ, 1844, Recherches sur les poissons fossiles, vol. 2, pt. 11, p. 280.

Horizon.—Lower Eocene.

Locality.—Isle of Sheppey.

Remarks.—Several Tertiary species of fossil acipenserids, described from isolated scutes and spines are at present indistinguishable from the scutes of this Recent *Acipenser*.

ACIPENSER LEMOINEI (Priem), 1902

Arius? lemoinei PRIEM, 1902, Soc. Géol. France Bull., ser. 4, vol. 1, p. 492, pl. 11.

Horizon.—Lower Eocene.

Locality.—Épernay, Marne, France.

Remarks.—This spine was referred to *Acipenser* by its original describer in 1904 (Soc. Géol. France Bull., ser. 4, vol. 4, p. 47) and is possibly identical with the preceding species.

ACIPENSER ORNATUS Leidy, 1873

Acipenser ornatus LEIDY, 1873, Acad. Nat. Sci. Philadelphia Proc., vol. 25, p. 15.

Horizon.—Miocene.

Locality.—Virginia.

ACIPENSER MOLASSICUS Probst, 1882

Acipenser molassicus PROBST, 1882, Vereins für vaterländische Naturkunde in Württemberg, Jahreshefte, Jahrgang 38, p. 121.

Horizon.—"Molasse" = Miocene.

Locality.—Baltringen, Württemberg, Germany.

ACIPENSER TUBERCULOSUS Probst, 1882

Acipenser tuberculosus PROBST, 1882, Vereins für vaterländische Naturkunde in Württemberg, Jahreshefte, Jahrgang 38, p. 127.

Horizon.—"Molasse" = Miocene.

Locality.—Baltringen, Württemberg, Germany.

Remarks.—There are several records of *A. toliapicus* from the London Clay. *A. molassicus* and, particularly, *A. tuberculosus*

[1] Daimeries' "*Accipenser cretaceus*" (Annales de la Societe Royale Malacologique de Belgique, Année 1892, tome 27, page XVI) described from the Senonien [=Upper Cretaceous] apparently is not a sturgeon, but probably referable to the teleosts.

show rather strange sculpturing for an *Acipenser*. If these are not due to weathering or other processes of preservation, the typical examples well might belong to other genera.

Several previously unidentified isolated scutes and plates evidently referable to *Acipenser ornatus* are in the United States National Museum and the Chicago Natural History Museum. The following unpublished data of records of this form were made available through the courtesy of Dr. David H. Dunkle and Dr. Robert H. Denison, respectively. The material in the National Museum was collected by Wm. Palmer in July, 1919, near Cheasapeake Beach, Calvert County, Maryland in Miocene stratum No. 6 (Calvert) and is catalogued as USNM 14854. The scutes at Chicago (CNHM PF622) were obtained by an unrecorded collector from the Calvert Formation, middle Miocene, at Plum Point, Calvert County, Maryland in 1912. I could locate no fossil acipenserid material in the paleontological collections of the Philadelphia Academy of Natural Sciences or Princeton University.

As repeatedly indicated, the knowledge of fossil Acipenseridae is largely based on scutes and plates. The form described below, though badly crushed, is based on parts of the head, body and tail, plus some impressions.

Genus PROTOSCAPHIRHYNCHUS, n. gen.

Genotype.—Protoscaphirhynchus squamosus, n. sp.

Diagnosis.—An acipenserid fish superficially resembling *Scaphirhynchus* but differing in that the body is entirely covered by scale-like plates and scutes. *Protoscaphirhynchus* from: πρωτος first or early; *Scaphirhynchus* a genus of sturgeon.

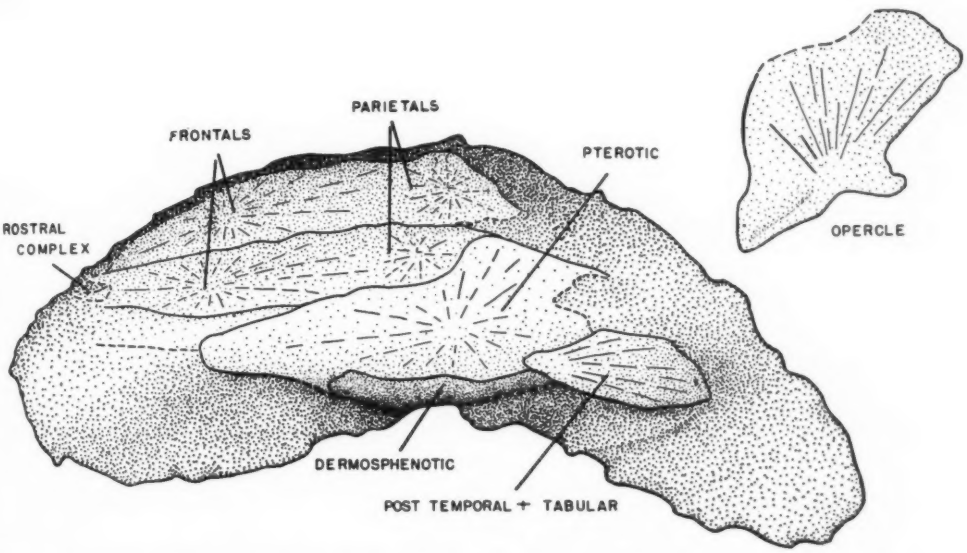
PROTOSCAPHIRHYNCHUS SQUAMOSUS, n. sp.

Holotype.—University of Michigan Museum of Paleontology No. 22210.

Horizon.—Upper Cretaceous, Hell Creek beds.

Locality.—Along a small tributary of Rock Creek in SE¼ sec. 36, T. 23 N., R. 43 E., ¼ mile west of Bonin school house, McCone County, Montana; about 24 miles SE of Fort Peck, Montana.

Diagnosis.—A completely armored acipenserid fish superficially resembling *Scaphirhynchus*, possessing a similarly keeled



TEXT-FIG. 1—*Protoscaphirhynchus squamosus*, n. sp. Semi-diagrammatic view of cranium, shown also as Pl. 132, fig. 2. The opercle, not visible on the block from this angle, is shown in the upper right. Drawn by S. H. Weitzman.

and scaled heterocercal tail but differing in the complete squamation of the body and possibly in having a relatively shorter head, although the latter point needs corroboration from additional material.

Description.—Fig. 2, Pl. 132 shows the dorsal aspect of the head of *Protoscaphirhynchus squamosus* and an outline of the interpreted elements. Since there is almost no trace of the sutures, the following measurements are merely approximations based on my interpretations. Total length of skull from broken dermosphenotic to remnants of rostral complex is 189 mm.; estimated greatest width of skull between parietals, ?70mm., length of the post-temporal (indistinguishable dorsally from the tabular), 47 mm.; length of parietals, ?70 mm.; greatest width of parietals, ?17 mm.; length of pterotic, ?75 mm.; length of frontals, ?27 mm. The left opercle[1] was bent underneath the skull and considerably crushed. The greatest vertical height of opercle is 58 mm.; its greatest width, 35 mm.; the distance from the posterior margin of the opercle to the pectoral spine, 32 mm.

Remnants of the rather poorly preserved body are now contained in a second slab shown by Pl. 132, fig. 1. Measurements and counts made on this specimen are as follows: estimated length from base of caudal peduncle to origin of anal, ?225 mm.; length of anal base, 63 mm.: anal rays, ?28; only two or three rays of the dorsal fin are visible. Fig. 3 is of the typical scaphirhynchid tail. The distance from caudal peduncle to tip of tail is ?90 mm. The pelvics appear to have ?19–20 rays and I estimate the pectoral to have 34 rays. The block containing the body has in addition the impression of two pectoral fins and one pelvic fin of a much larger fish seemingly identical with this form on the basis of ray counts and shape. A small block (not illustrated) contains a portion of the lateral main row of scutes. One complete plate is 22 mm. in greatest height and its length is 12 mm. The specific name *squamosus* is from the Latin in reference to the scale-like plates covering the body of this fish.

Relationships.—The discovery of a completely armored or scaled acipenserid fish of this antiquity lends considerable weight to the thesis that bone and external armor preceded cartilage and an unarmored or naked condition in this group. Furthermore, the finding of *Protoscaphirhynchus squamosus* side by side with a polyodontid fish indicates that if the Polyodontidae are an offshoot of the acipenserids, differentiation must have taken place considerably earlier than Upper Cretaceous. Furthermore, the Acipenseridae are usually placed by most systematists in the same order with the Chondrosteidae. The Chondrosteidae are, as far as known, unarmored and naked fishes. Following the hypothesis that scales and armor precede a naked condition and that in most instances evolution is irreversible, it does not seem likely that the Chondrosteidae form the basal stock of the primitively armored acipenserids and polyodontids, and may well be assigned to a new order distinct from the Acipenseriformes.

[1] Tatarko, 1936, Trav. Inst. Zool. & Biol. Acad. Sci. Ukraine, vol. 10, p. 48–50, believes the large opercular element of sturgeons is really the subopercle. I have no evidence to shed light on this matter.

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MANUSCRIPT RECEIVED JANUARY 24, 1955

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1209–1224, 2 TEXT-FIG., SEPTEMBER 1956

QUANTITATIVE TRILOBITE STUDIES I. THE STATISTICAL DESCRIPTION OF TRILOBITES

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ABSTRACT—Quantitative description is becoming increasingly necessary in studies of trilobites. However, the molting habit of these animals makes the arithmetic mean an unsatisfactory descriptive tool for ordinary samples. Likewise, ratios, which are now widely used in descriptions, are unsound because they are usually not comparable between molt stages. The most satisfactory descriptive tool seems to be linear regression ($Y=a+bX$), at least for samples of meraspid and holaspid specimens. No need has been found in *descriptive* work for the allometric growth formula $Y=bX^k$, although its use in other problems has not been considered. The computation and comparison of regressions are described, and a minimum list of statistics recommended for normal description is given.

INTRODUCTION

THE present paper summarizes seven years of study of the measurement of the dorsal shield of trilobites and evaluation of the statistical treatments to which the resulting numerical data may be subjected, as a supplement for the usual qualitative descriptive procedures. What is written here is by no means exhaustive, for each new sample of trilobites brings some hitherto unsuspected problems and suggests some new avenues of approach to trilobite biometry. In addition, some methods, such as the use of Chi-square and the coefficient of variation (V) have been omitted entirely, pending further study, but inasmuch as the entire field of trilobite statistics is in the formative stage is may not be amiss to present this summary in the hope that it may serve as an aid to others studying the subject.

ACKNOWLEDGMENTS

During 1953 a draft of this article was duplicated under a grant-in-aid from the Graduate Research Council, University of Wyoming. Copies were distributed to a number of colleagues who were asked for criticisms and suggestions. Many of those thus imposed upon made lengthy comments which have been freely incorporated in this revised version. I am deeply indebted to the following friends, all of whom have given me the benefit of their opinion and counsel: Christina Lochman Balk, W. C. Bell, A. J. Boucot, B. H. Burma, P. E. Cloud, Jr., W. R. Evitt, E. A. Frederickson, Gunnar Henningsmoen, Lehi Hintze, B. F. Howell, R. D. Hutchinson, John Imbrie, Teiichi Kobayashi, R. L. Miller, C. A. Nelson, A. R. Palmer, R. J. Ross, Jr., Paul Tasch, H. B. Whittington, and J. L. Wilson. Whatever merit this presentation may have derives in large part from their generous aid.

THE PLACE OF QUANTITATIVE DATA IN TRILOBITE STUDY

The most obvious result of trilobite measurement is the accumulation of numerical data which supplement the qualitative information commonly given in descriptive work. Note that these data *supplement* but do not *supplant* the qualitative data. Statistical treatment of the problems of trilobite description, ontogeny and taxonomy will, if properly handled, lend a new precision to the work and will open up new avenues of approach that may not be subject to qualitative attack, but the critical factor in both methods—the interpretive ability of the individual investigator—is the same.

The accurate measurement of trilobites and the graphic and statistical treatment of the resulting data seemto me to serve three fundamental paleontologic purposes. First, they serve the student of the original collection in his attempts to distinguish valid from spurious divisions among his specimens. Second, they provide subsequent students with numerical data by means of which their own collections can be compared objectively with the type lot even in the

absence of the original specimens. And finally, quantitative data, properly handled, can assist in taxonomic work at the specific and subspecific levels by pointing out valid differences and similarities among groups, and at supraspecific levels by pointing out similarities and differences among species.

Assistance in original investigations.—As the use of quantitative analysis becomes more general statistical treatment will be increasingly used in original analyses to make clear to the student whether his data show valid divisions. Burma (1949) has already demonstrated this sort of procedure in the case of two groups of *Pentremites godoni* in which the differences were not clearly enough established to be accepted without question on a qualitative basis alone.

Quantitative methods are of great assistance in the study of trilobite ontogeny, but here a graphic approach is an especially valuable adjunct to the more formal statistical procedures. The treatment of ontogeny has been discussed by Burma (1948, p. 741–749), Olson & Miller (1951, p. 213–217), Olsen (1951, p. 523–524), Shaw (1952, p. 465, text-fig. 3), and others. In its simplest form it consists of arranging the specimens in order of size for some selected dimension that is assumed to represent growth stage (or "Time") reasonably well and then plotting other dimensions as dependent variables. It is in such studies that the need for linear regression rather than the mean and standard deviation becomes most apparent.

Assistance in subsequent studies.—One of the most useful purposes served by publishing quantitative data is that it allows statistically significant comparisons to be made in the absence of the original specimens. In a case where the coefficients of regression have been presented together with other pertinent statistics it is possible for a subsequent student to compare either a single specimen or a group of specimens with the type lot.

A case of the converse sort arises when measurements have been given for the type specimen alone, and it is wished to compare a later lot with the type. The presence of type specimen measurements alone in much of the older literature assures that this situation will arise frequently. An example of this has been mentioned previously in another connection without citing the statistical treatment involved (Shaw, 1950). In examining a Lower Ordovician fauna (erroneously dated Late Cambrian in earlier papers—see Shaw, 1955) from northwestern Vermont a *Parabolinella* was discovered; routine comparison with more than 30 described species of the genus led to the qualitative conclusion that the Vermont form was the same as one described from Argentina as *Parabolinella triarthroides* Harrington, 1938; however, this identification presented a problem because it meant that *P. triarthroides* had a geographic range far in excess of that expected for such marine animals. In order to check the qualitative identification it was decided to compare the Vermont collection with the holotype, for which some measurements had been given. To do this, lines of regression were calculated for several combinations of characters among the Vermont specimens: then the dimensions of the holotype were substituted in the regression formulae and the differences between the observed and computed values tested for significance by means of the standard error of estimate. In no case were statistically significant differences found (Table 1).*

It is not desired to labor this case for itself alone. The importance of it lies in its use as an example of how statistical analysis may strengthen an original qualitative opinion and serve as basis for comparison of a group of specimens with the unavailable holotype.

* Not all of the measurements of the holotype used in Table 1 were given in Harrington's text. Harrington gave total cranidial length (A_1), intraoccipital glabellar length (B), and "width of the glabella," which, because of the glabellar shape in *P. triarthroides*, is essentially equal to the width of the occipital ring (K). From K we can derive the width of the posterior limb (L), which is half of the difference between the width of the occipital ring (K) and the posterior cranidial width (J_1), thus:

$$J_1 = K + 2L = 5.2 \text{ mm.}$$

$$L = \frac{J_1 - K}{2} = 1.6 \text{ mm.}$$

L nearly equals the width of the chord of the posterior limb (L_1) in this case because of the flatness of the limbs and has been used in the comparisons in Table 1 as equal to L_1; while this

TABLE 1

Regressions from Vermont Sample ($Y_e=a+bX$)	Standard Errors of Estimate (S_Y)	r	Sample Size (N)	Holotype: Observed Independent Variable (X)	Holotype: Computed Dependent Variable (Y_e)	Holotype: Observed Dependent Variable (y)	Deviation (Y_e-y)	$\left(\frac{t}{\frac{Y_e-y}{S_Y}}\right)$	D.f.	P
$B_1=0.72A_2+0.22$	0.15	.998	37	2.8	2.24	2.1	+0.14	+0.93	36	>0.10
$A_2=1.38B_1-0.29$	0.20			2.1	2.90	2.8	+0.10	+0.50		>0.50
$B_1=1.11K+0.21$	0.34	.992	37	2.0	2.43	2.1	+0.33	+0.97	36	>0.10
$K=0.89B_1-0.13$	0.43			2.1	1.74	2.0	−0.26	−0.60		>0.50
$D=0.41A_2+0.33$	0.13	.966	24	2.8	1.48	1.4	+0.08	+0.62	23	>0.50
$A_2=2.41D-0.75$	0.32			1.4	2.63	2.8	−0.17	−0.53		>0.50
$J_5=0.86A_2+0.63$	0.46	.985	22	2.8	3.04	3.3	−0.26	−0.57	21	>0.50
$A_2=1.13J_5-0.57$	0.51			3.3	3.16	2.8	+0.36	+0.71		>0.10
$L_1=0.77K-0.22$	0.22	.986	20	2.0	1.52	1.6	−0.08	−0.36	19	>0.50
$K=1.26L_1+0.04$	0.28			1.6	2.06	2.0	+0.06	+0.06		>0.50
$B_1=1.76D-0.36$	0.20	.997	24	1.4	2.11	2.1	+0.01	+0.05	23	>0.50
$D=0.56B_1+0.22$	0.12			2.1	1.40	1.4	0.00	0.00		1.00
$A_1=1.05A_2-0.01$	0.07	.993	32	2.8	2.93	3.0	−0.07	−1.00	31	>0.10
$A_2=0.95A_1-0.02$	0.06			3.0	2.83	2.8	+0.03	+0.50		>0.50

Assistance in taxonomy.—Graphic analysis and the use of multivariate analysis should permit the more objective separation of groups on the specific and subspecific level. In many cases now in the literature separations have been recognized between subspecies or species almost solely on the basis of geographical isolation without any real demonstration of significant quantitative difference between groups. While it is true that geographically isolated faunules are frequently slightly different from one another an objective, quantitative evaluation of these differences should be made before an attempt is made to erect separately named taxonomic categories.

Statistical analysis also appears to have application at higher taxonomic levels in the study of trilobites although sufficient data have not yet been accumulated to demonstrate concretely its use. Preliminary investigations have suggested that certain of the suprageneric categories, such as superfamilies or suborders, may have constant or nearly constant values for the coefficient of regression (b) in the equation for linear regression. To cite an obvious case, the regression of glabellar length on total cranidial length is more or less constant among members of the superfamily Bathyuriscidea and among the members of the superfamily Ptychopariidea, but the average valve of the coefficient of regression can hardly be similar for both superfamilies because the glabellae of the former are long and those of the latter, short. So far, large suites of specimens representing numerous genera within a superfamily have not been available for testing of this hypothesis, but appears to be a potentially fruitful line of statistical research.

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is technically improper, the slightly greater length of L_1, if it could be obtained, would not be enough to cause a significant deviation.

The available measurements may, thus, be summarized:

From Harrington	*Computed*
$A_1=3.0$ mm.	$A_2=2.8$ mm.
$B=2.0$	$B_1=2.1$
$K=2.0$	$D=1.4$
	$J_5=3.3$
	$L=1.6$

The symbols not defined above are: A_2 = length (sag.) of cranidium from rear of occipital ring forward to marginal furrow. B_1 = length of glabella including occipital ring. D = distance (sag.) from rear of occipital ring to point opposite centers of palpebral lobes. J_5 = width (tr.) of cranidium behind the palpebral lobes.

The need for hypothesis in testing.—As statistical treatment becomes more common in the study of trilobites there will probably arise a problem occasioned by the use of statistics as though they were themselves capable of making biological distinctions. Statistical analysis cannot be the initial step in the study of trilobites; it must be used to check qualitative opinions upon which the investigator has already settled. Burma (1949) has illustrated the only sound approach to statistical analysis on the specific level in his discussion of *Pentremites godoni*. He first made the qualitative assumption that there were two varieties of *P. godoni* (not using the term "variety" in a formal taxonomic sense), and then he checked his hypothesis quantitatively. It is essential that the qualitative opinion come first so that the quantitative analysis may have an hypothesis to test.

STATISTICAL METHODS APPLICABLE TO TRILOBITES

In the preceding section three overlapping uses for statistical analysis were outlined: (1) original discrimination, (2) description for subsequent students, and (3) taxonomy. The second of these uses will be the principal topic of the remainder of this paper.

Measures of central tendency.—The most common statistical methods are based on the assumption that repeated samples from a population tend to cluster about a central point, of which the arithmetic mean ($\bar{x}$) is the most commonly used estimate, while the dispersion of such samples is measured by the standard deviation (σ). However, molting animals such as trilobites do not produce fossilizable remains in a normally distributed manner but rather in some as-yet-unknown right-skewed curve so that it is improper to use measures of central tendency that assume normal distribution to describe *unmodified* trilobite samples, for their distribution does not seem to be normal. Of course, an individual fossil population may assume a normal distribution as a result of modifications during burial, diagenesis, or collection, but this does not make the mean and standard deviation generally applicable. The only time when these two statistics would find practical use would be when a sufficient number of specimens of a single age group (usually determined by the size of some dimension) were available, but such quantities of specimens are only rarely obtainable among trilobites, and, moreover, such analysis would not be of much general value unless some method were available for applying the information obtained to larger and smaller individuals (i.e., to other age groups).

Thus, measures of central tendency in normal populations can be of use only in the description of samples of single age groups of trilobites; some other methods must be employed to describe entire samples of mixed age groups.

The use of ratios.—It is now a rather widespread custom to describe the trilobite, particularly the cephalon, by the use of ratios. This has been encouraged especially by Lochman (1947, p. 60–61), who has recommended several proportions to be used as standard descriptive tools; some proportions she has regarded as of generic value; others, as of specific value. The use of ratios has some advantages over the more elaborate statistical techniques: First, there is the ease of calculation; it is a simple matter to calculate the ratios of several parts of the cephalon and then to derive the mean ratios with the standard deviations. Second, there is the widespread understanding of the meaning of a ratio. Third, there is the independence of the ratio from the size of the measurements from which it is computed. However, all of these advantages seem to be outweighed by some serious deficiencies when ratios are applied to trilobites:

First, a ratio is a secondary statistic; it is not in itself an observation but the quotient of two observations, *each of which has its own variance*. Simpson & Roe (1939, p. 8–10) have pointed out that ratios often vary more than their constituent dimensions when those dimensions represent continuous variates. The effect of this greater variance in ratios would be to mask differences that are significant in the original data.

A second, less obvious property of ratios is that any departure of the regression of the two variates from strict rectilinearity will cause statistically significant differences to

appear where there are none in the original data. In practice, however, this does not seem to be critical because almost all trilobite samples thus far studied have shown a rectilinear rather than a curvilinear pattern.

The third, and most serious defect of ratios is that they are not, except in the special case discussed below, applicable to more than one growth stage at a time; this is because of the fact that the ratio expresses only the proportion

$$\frac{Y}{X}=b$$

where X and Y are the two variates and b is the coefficient of regression, whereas the general expression for any rectilinear distribution is

$$Y=a+bX.$$

As can be seen, these two expressions are equivalent only when

$$a=0$$

which is to say, when the distribution passes through the origin. In *any other case* (i.e., if a has either positive or negative value) it will be impossible to calculate a valid mean ratio for the entire sample because each point in the array (i.e., each growth stage of the animal) has its own characteristic ratio value, which is at best only approximately equal to that of other points in the array. In practice, about 1%–2% of the arrays studied have passed through the origin, and a moment's reflection would show that this should be expected, for the passage of the array through the origin implies that the two dimensions under consideration were equal in size at the earliest growth stage, and this is certainly not always true.

An example of the differences between ratios that can be obtained at either end of a growth series that does not pass through the origin can be found in *Parabolinella triarthroides*. This species demonstrates a strong rectilinearity in the relation between the glabellar length (including the occipital ring) and the sagittal length of the cranidium, measured from the anterior marginal furrow to the rear of the occipital ring; the array does not pass through the origin (Text-fig. 1). When the ten smallest specimens and the ten largest specimens are chosen as two test groups and the ratio

$$\frac{\text{occipital glabellar length } (B_1)}{\text{intramarginal cranidial length } (A_2)}$$

is calculated for each individual, the two groups show mean ratios and standard deviations of the ratios as shown in Table 2.

TABLE 2—MEAN RATIOS AND STANDARD DEVIATIONS OF THE RATIOS OF TWO SELECTED LOTS OF *Parabolinella triarthroides* HARRINGTON, 1938

Lot	Mean Ratio	Standard Deviation
Ten smallest specimens (1)	.816	0.052
Ten largest specimens (2)	.742	0.027

To test the significance of the difference between the mean ratios of these two groups the standard error of the difference of the means (σd_m) was calculated:

$$\sigma d_m=\sqrt{\frac{\sigma_1^2}{N_2}+\frac{\sigma_2^2}{N_1}}$$

$$=\sqrt{\frac{(0.052)^2}{10}+\frac{(0.027)^2}{10}}$$

$$\sigma d_m=0.019.$$

The proportion

$$t=\frac{\text{difference of the means } (d_m)}{\sigma d_m}$$

then gives us a measure of the significance of the difference of the means of the two groups of specimens. In this case

$$t=\frac{.816-.748}{.019}=3.58.$$

Entering the table of t with

$$N_1+N_1-2=18$$

degrees of freedom (*D.f.*) we find that $P<0.01$, showing a highly significant statistical difference between the two groups of ratios. Thus the application of ratios to the two ends of the ontogenetic series is invalid. Similar cases could be made in any species, but this illustration suffices as a demonstration of the general inapplicability of ratios to growth *series* as opposed to growth *stages*. We shall return to these two samples again.

A case of the converse sort, in which the

use of ratios *conceals* the fact that the data are *not* significant, as they are presented, will be discussed following the description of the coefficient of correlation (r).

There are some cases in which ratios can be used effectively to convey particular types of information. Such a case is Weller's data on the relative decrease in the number of pleural segments of the pygidia of proetid trilobites as compared to the number of axial segments, from Kinderhook to Early Permian time (Weller, 1937, p. 344). But for description of trilobite species the use of ratios cannot be recommended.

Rectilinear or allometric growth?—Burma (1948, p. 741–747) has ably advocated the use of Huxley's heterogonic growth formula

$$Y=bX^k$$

but none of the samples of meraspid or holaspid trilobites thus far studied has fallen far enough from a rectilinear array to warrant the use of the heterogonic formula; in this paper Text-fig. 1 and 2 show this. It is possible that when complete ontogenetic series, including protaspids, are analyzed some evidence of the existence of allometric growth may appear, but to date no such data have been obtained.

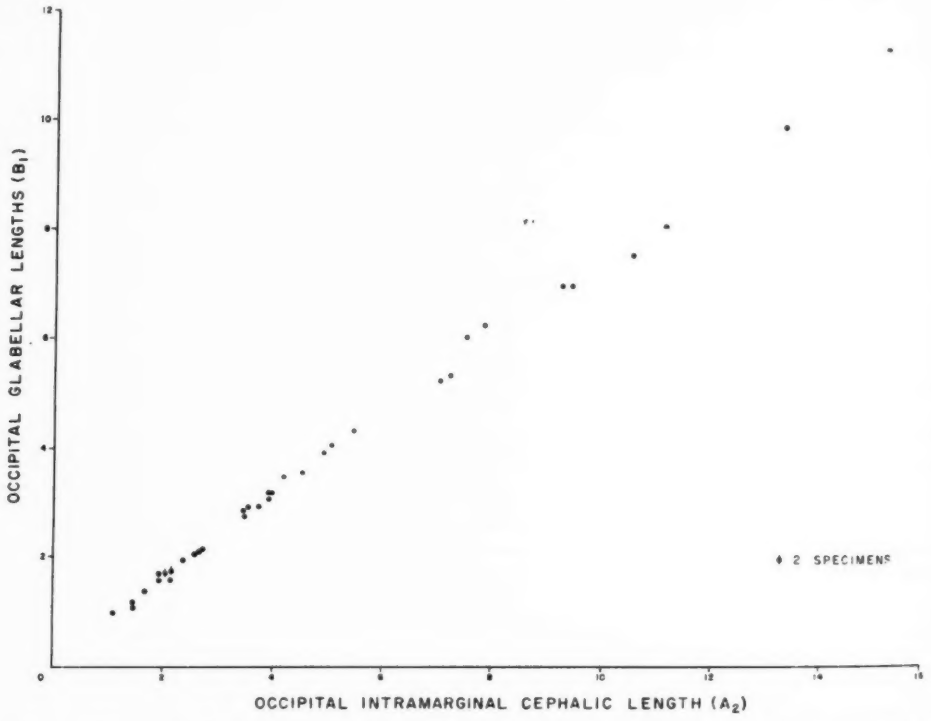
RECTILINEAR REGRESSION

If the graph of any selected pair of dimensions of a trilobite is rectilinear, the best expression of the relationship between the dimensions is the formula for rectilinear regression

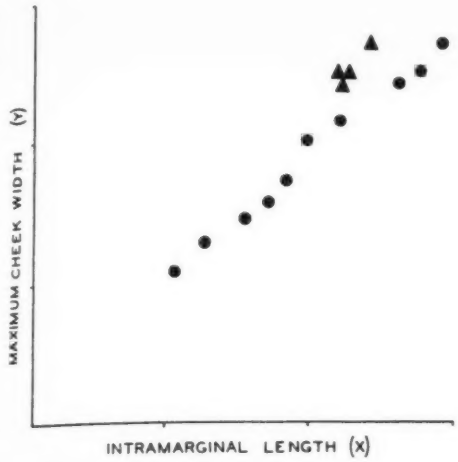
$$Y=a+bX.$$

However, it cannot be too strongly emphasized that the graph itself must show the rectilinearity; each case must be checked individually. Thus, construction of a graph is the normal first step in any analysis. After the graph has shown that rectilinear regression is present the formula can be computed as follows:

Computation of the line of regression.—



TEXT-FIG. 1—Graph of 37 specimens of *Parabolinella triarthroides* Harrington, 1938, from the basal Highgate formation (Tremadocian), at Highgate Falls, Vermont.



TEXT-FIG. 2—Graph of the cranidia of *Geragnostus bisectus* (Matthew), 1892, var. *typica* Shaw, 1951 (circles) and *G. bisectus* var. *brevis* Shaw, 1951 (triangles). Graph three millimeters on each side. Raw data given in Table 8.

The computation of the line of regression with the general formula

$$Y=a+bX$$

is a relatively simple process and may be illustrated by the computation of the first of the regressions given in Table 1 for *Parabolinella triarthroides*, wherein the intramarginal cranidial length (A_2) is compared to the total glabellar length (including the occipital ring) (B_1). The graph of this array (Text-fig. 1) indicates that rectilinear regression is applicable so the following computations are carried out:

(1) The arithmetic mean of both sets of dimensions is computed [$\bar{x}$, $\bar{y}$].

(2) Each observation [x or y] is successively subtracted from its appropriate mean and the deviation obtained [$(\bar{x}-x)$; $(\bar{y}-y)$].

(3) These deviations are each squared [$(\bar{x}-x)^2$; $(\bar{y}-y)^2$].

(4) These squared deviations are summed [$\Sigma(\bar{x}-x)^2$; $\Sigma(\bar{y}-y)^2$].

(5) The deviation obtained for each pair of observations are multiplied, care being taken to record the sign of the product properly [$(\bar{x}-x)(\bar{y}-y)$].

(6) The products are summed algebraically [$\Sigma(\bar{x}-x)\ (\bar{y}-y)$].

(7) The two regressions $Y=a+bX$ and $X=a+bY$ are calculated by substitution in the following formulae:

$$Y=\bar{y}+\frac{\Sigma(\bar{x}-x)(\bar{y}-y)}{\Sigma(\bar{x}-x)^2}(X-\bar{x})$$

and

$$X=\bar{x}+\frac{\Sigma(\bar{x}-x)(\bar{y}-y)}{\Sigma(\bar{y}-y)^2}(Y-\bar{y})$$

Note that there are other, shorter methods for computing regressions alone, and they can be found in any standard textbook, but these shorter methods do not yield all of the data needed in the additional computations to be discussed below, and the advantage of the "short" methods is lost if individual statistics must be later computed separately.

COMPLEMENTARY STATISTICS

Following the computation of the regressions, which contain the two coefficients of regressions (b_1 and b_2), several additional statistics should be calculated. These are the coefficient of correlation (r), the standard error of estimate (S_Y), and the standard error of the coefficient of regression (σ_b).

Coefficient of Correlation

The first of the aeditional statistics is the coefficient of correlation (r), which measures the degree of perfection in the relationship between X and Y. It ranges between zero, which shows no correlation, and unity, which indicates perfect correlation. As a general procedure, the calculation of r may precede calculation of the other complementary statistics, for if r is not significant no other statistics need, as a rule, be computed.

The coefficient of correlation is the square root of the product of the two coefficients of regression (b_1 and b_2), which were obtained in calculating the regressions formulae:

$$r=\sqrt{(b_1)(b_2)}$$

Test of the significance of r.—It is not convenient to test the value of r directly because r is not distributed normally, but by converting r to z by means of tables (Snedecor, 1946, p. 152; Arkin & Colton, 1950, p. 122, etc.) we obtain a measure of r that

is normally distributed, with a standard error of estimate of

$$\sigma_z = \frac{1}{\sqrt{N-3}}$$

where N is the number of *pairs* of observations in the sample.

If $z - 2\sigma_z$ is greater than zero there is less than a 5% chance that the value of r obtained is due to random chance; if $z - 3\sigma_z > 0$ there is less than a 1% chance of the observed value of r being due to random chance. In making this check z may be used as positive without regard to the sign of r. By recovering the values of r corresponding to $z + 3\sigma_z$ and $z - 3\sigma_z$ we may also set the 1% fiducial limits on r.

An example of the application of r.—To illustrate how the coefficient of correlation may serve as a test of trilobite data we may turn to *Ditomopyge olsoni*. Weller (1935, p. 507, fig. 4–8) figured five pygidia of this species and later (Weller, 1937, p. 344) tabulated the counts of axial and pleural segments for the figured specimens. These counts were converted into ratios designed to demonstrate that the value of the ratio

$$\frac{\text{pleural segment count (Pl)}}{\text{axial segment count (Ax)}}$$

decreases progressively during adolescence. The data are retabulated in Table 3. The question we may ask is: *With such a small sample may not the apparent decrease in ratio be due solely to chance arrangement?* There is no way to answer this question by testing the ratios themselves, but if we derive the regression formulae

$$\text{Pl} = 0.465\text{Ax} + 2.2 \text{ mm.}$$

$$\text{Ax} = 0.800\text{Pl} + 4.8 \text{ mm.}$$

TABLE 3—RATIOS OF PLEURAL TO AXIAL SEGMENTS IN A SERIES OF IMMATURE PYGIDIA OF *Ditomopyge olsoni* (FROM WELLER, 1937, P. 344). FIGURED BY WELLER (1935), p. 507, FIGS. 4–8)

Figure	Pleural Segments (Pl)	Axial Segments (Ax)	Ratio $\frac{\text{Pl}}{\text{Ax}}$
4	5	7	.714
8	6	12	.500
7	7	11	.636
5	8	10	.800
6	9	12	.750

and from them compute the coefficient of regression

$$r = \sqrt{(.465)(.800)} = .610$$

we may test this figure by means of z, as outlined above:

$$z = .708$$

$$\sigma_z = \frac{1}{\sqrt{5-3}} = 0.707$$

From this it can be seen that $z = 0$ lies almost exactly at $z - \sigma_z$; this means that there is almost a 14% chance of getting the value $r = .610$ in a sample of five by random chance and that, therefore, the apparent correlation between axial and pleural segment counts should be rejected as unproved on the basis of the data given. On the other hand, the sample does not prove that no relation exists. What we have demonstrated is only that the data now available are insufficient to support the conclusions that were based upon them and, further, that it was not possible to discern this lack of significance in the original ratios.

It is of interest to inquire how large a sample would be needed to demonstrate the significance of $r = .610$ in *D. olsoni*. To determine this we may reverse our testing procedure and use one-third of the value of z as the value of σ_z, thus, making $z - 3\sigma_z = 0$, which is the minimum acceptable value. Having decided the value of σ_z

$$\sigma_z = .708/3 = .236$$

for *D. olsoni*, we may alter the formula

$$\sigma_z = \frac{1}{\sqrt{N-3}}$$

to

$$N = \frac{1}{\sigma_z^2} + 3$$

and by substitution

$$N = \frac{1}{(.236)^2} + 3$$

$N = 21$ (rounded upward to nearest full digit)

Thus, we must have a minimum of 21 specimens with $r = .610$ before we can regard the correlation as highly significant in the statistical sense.

Minumum values of r in small samples.—In order that checks may be made quickly

and without recourse to the computation of s Table 4 has been computed to give at a glance the minimum significant values of r at the 1% and 5% fiducial levels for samples of 5 to 30 specimens. Note that Table 4 cannot be used where more than two variates are compared: for such tables see Snedecor (1946, p. 35) or Arkin & Colton (1950, p. 140). In Table 4 all values of r are rounded to the next highest digit, for they are used as lower limits.*

TABLE 4—MINIMUM SIGNIFICANT VALUES OF r FOR SMALL SAMPLES AT THE 1% AND 5% FIDUCIAL LEVELS

Sample Size (Pairs)	1%	5%	Sample Size (N)	1%	5%
5	.972	.889	18	.650	.476
6	.940	.820	19	.636	.463
7	.906	.762	20	.622	.451
8	.873	.714	21	.608	.440
9	.843	.674	22	.597	.430
10	.813	.639	23	.586	.420
11	.787	.610	24	.575	.411
12	.762	.584	25	.565	.403
13	.740	.561	26	.555	.395
14	.719	.539	27	.546	.387
15	.700	.522	28	.537	.380
16	.682	.505	29	.530	.374
17	.666	.489	30	.522	.368

The use of this table may be illustrated by analysis of the data provided by Weller (1935, p. 512) on the length of the genal spines of *Ditomopyge olsoni* as compared to the anterior length of the free cheeks. These data were supplied as ratios orginally, but by measurement of the sketches and comparison with the ratios the original millimeter measurements were recovered. The regression formulae are:

$$An = 1.449\,Sp - 0.254$$

$$Sp = 0.683\,An + 0.196$$

* It should be noted that tables with a similar purpose such as those in Snedecor (1946, p. 149) give higher values of r because they are computed on a different basis from the null hypothesis—under which the question is asked, "What is the largest value of r we may expect from a population with zero correlation 1% (or 5%) of the time with a given sample size?". Table 4 was computed to answer the question, "What is the smallest value of r that we may rely upon 99% or 95% of the time as not having come from a population with zero correlation?".

where:

An = anterior length of free cheek

Sp = length of genal spine

with the standard errors of estimate:

$$S_{An} = 0.170$$

$$S_{Sp} = 0.117$$

In this case the coefficient of regression:

$$r = .995$$

and there are nine free cheeks in the sample (N = 9). So we simply note in Table 4 the value of r corresponding with a sample size of nine. This value we find to be .843, far lower than our value of .995; thus, without further test we may accept the correlation of spine length and cheek length as highly significant.

Standard Error of Estimate (S)

The second complementary statistic needed is the standard error of estimate or what may be called the "standard deviation from the regression" (S). This statistic is comparable to the standard deviation of the mean (σ) in populations with a normal distribution and may be used to set fiducial limits around the line of regression in a manner similar to that applied to the standard deviation. Thus, any values equal to:

$$Yc \pm 2S_Y$$

(where Yc = the calculated value of Y) should include 95% of all individuals with a chosen value of X and the limits: $Yc \pm 3S_Y$ will normally include 99% of all individuals with the chosen value of X. The standard error of estimate is computed as follows: (1) substitute the observed values of X in the regression formula and compute corresponding values of the dependent variable (Yc). (2) Subtract the observed values of y from the computed values (Yc) and square the deviations $[(y - Yc)^2.]$ (3) The squared deviations are summed $[\Sigma(y - Yc)^2]$ (4) The standard error of estimate computed,

$$S_Y = \sqrt{\frac{\Sigma(y - Yc)^2}{N - 2}}$$

where N is the number of pairs of observations.

The value of S_X is computed in a like manner.

Comparison of regressions.—In descriptive work the presentation of the formula for the line of regression ($Y=a+bX$) with its standard error of estimate (S_Y) usually suffices to present the data on the original specimens, and in addition, it permits later comparison with other *specimens*, but in the case of two *species*, we will normally wish to compare the samples as a whole and not as individual specimens; in short, we will wish to know whether the coefficients of regression (b) for the same pairs of variates are different or the same in the two species. We do this by computing the standard error of the difference between the coefficients of regression (σd_b) according to the method put forth by Simpson & Roe (1939, p. 278). We may illustreate this comparison by two examples chosen from *Catillicephala lata* and *C. fowleri.*

The first comparison is that between the regressions for the width of the glabella opposite the mid-points of the eyes of the sagittal glabellar length including the occipital ring (Shaw, 1952, p. 465, text-fig. 3D). In presenting the data previously, the glabellar width opposite the eyes was designated M; it is here called K_1. The sagittal glabellar length including the occipital ring (B) is unchanged. The qualitative discussion previously published pointed out that *C. fowleri* has a wider glabella than *C. lata* for an equal glabellar length, and the graph seems to confirm the assumption. The problem is to determine whether, with the small samples available, the distinctive graphs might not be due to chance alone.

Two methods are available to compute σ_{d_b} and both are illustrated here. The first uses the data commonly published and is derived as follows:

$$\sigma_{d_b}=\sqrt{\frac{(N_1)(\sigma_{x_1}^2)(1-r_1^2)+(N_2)(\sigma_{Y_2}^2)(1-r_2^2)}{N_1+N_2-4}\left(\frac{1}{(N_1)(\sigma_{x_1}^2)}+\frac{1}{(N_2)(\sigma_{x_2}^2)}\right)}$$

where:

N_1 = number of pairs of observations in the first sample (*Catillicephala lata* in this example)

N_2 = number of pairs of observations in the second sample (*C. fowleri* in this example)

$\sigma_{Y_1}^2$ = variance of the dependent variate (Y) in the first sample computed by the formula:

$$\sigma_{Y_1}^2=\frac{\Sigma(y-y)^2}{N}$$

$\sigma_{Y_2}^2$ = variance of the dependent variate second sample, similarly computed

r_1 = coefficient of correlation of the first sample

r_2 = coefficient of correlation of the second sample

$\sigma_{X_1}^2$ = variance of the independent variable variable (X) in the first sample from the formula:

$$\sigma_X^2=\frac{\Sigma(x-x)^2}{N}$$

$\sigma_{X_2}^2$ = variance of the independent variate in the second sample

The comparison of regressions can be made using both variables, successively, as the independent variable, but for the present example for glabellar length will be chosen as the independent variable so that our formula for regression becomes:

$$K_1=a+b\ B$$

TABLE 5—DATA FOR COMPARISON OF REGRESSIONS $K_1=a+bB$ IN *Catillicephala Lata* (RAYMOND), 1937, AND *C. fowleri* SHAW, 1952

	C. lata	*C. fowleri*
$K_1=a+bB$	$K_1=0.815B+0.06$	$K_1=0.965B+0.50$
N	8	7
r^2	.9837	.9891
$\sigma_{K1}^2(=\sigma_Y^2)$	2.4775	2.5700
$\sigma_B^2(=\sigma_X^2)$	3.6588	2.4200

It is not necessary to publish in full all the computations for the regressions used in these examples, for the procedure is identical with that already given. The pertinent data are given in Table 5. Substitution in the formula gives:

$$\sigma_{d_b}=\sqrt{\frac{(8)(2.4775)(1-.9837)+(7)(2.57)(1-.9891)}{8+7-4}\left(\frac{1}{8(3.6588)}+\frac{1}{7(2.42)}\right)}$$

$$=\sqrt{\frac{0.323066+0.196091}{11}\left((0.0342+0.0590\right)}$$

$$=\sqrt{0.047196\times 0.0932}$$

$$=\sqrt{0.004399}$$

$$\sigma_{d_b}=0.0663$$

To test whether the coefficients of regression (b) are significantly different we divide their difference by σ_{d_b}, thus:

$$t=\frac{0.965-0.815}{0.0663}$$

$$t=2.26$$

The value of t can be compared with any of the many available tables of t (e.g., Arkin & Colton, 1950, p. 116). In this case our degrees of freedom are:

$$D.f.=N_1+N_2-4=8+7-4=11$$

Our table of t shows that for 11 degrees of freedom our value of $t=2.26$ lies between 0.05 and 0.02; in other words, there are less than five and more than two chances in 100 that the differences between the coefficients of regression could be due to chance alone. Thus, since $P<.05$, which is regarded as significant, although not highly significant, we may regard the coefficients of regression as different in spite of the small samples involved.

The second illustration which *Catillicephala lata* and *C. fowleri* provide is the comparison of regressions involving the sagittal glabellar length (B) and the post-occipital, mid-palpebral distance (D). The raw data and graph have been presented previously with the same symbols (Shaw, 1952, text-fig. 3E). In this case we may use the alternative formula which utilizes the original data and is, therefore, slightly more accurate than the previous formula, which is subject to rounding errors.

$$\sigma_{d_b}=\sqrt{\frac{(\Sigma[(y-\bar{y})^2]_1)(1-r_1^2)+(\Sigma[(y-\bar{y})^2]_2)(1-r_2^2)}{N_1+N_2-4}\left(\frac{1}{\Sigma[(x-\bar{x})^2]_1}+\frac{1}{\Sigma[(x-\bar{x})^2]_2}\right)}$$

where:

$\Sigma[(y-\bar{y})^2]_1$ = sum of squares of the deviations from the mean ($\bar{y}$) of the dependent variable in the first sample

$\Sigma[(y-\bar{y})^2]_2$ = sum of squares for the second sample

$\Sigma[(x-\bar{x})^2]_1$ = sum of squares of the deviations from the mean ($\bar{x}$) of the independent variable in the first sample

$\Sigma[(x-\bar{x})^2]_2$ = sum of squares in the second sample

All other symbols are as in the previous example, and, as before *C. lata* is the first sample, and *C. fowleri* is the second. The pertinent data are given in Table 6. Substitution gives us:

$$\sigma_{d_b}=\sqrt{\frac{(12.0550)(1-0.9469)+(4.96)(1-0.967)}{7+6-4}\left(\frac{1}{27.3722}+\frac{1}{17.27}\right)}$$

$$=\sqrt{\frac{0.5196+0.1637}{9}\left(0.0365+0.0579\right)}$$

$$=\sqrt{(0.0759167)(0.0944)}$$

$$=\sqrt{0.007167}$$

$$\sigma_{d_b}=0.0847$$

TABLE 6—DATA FOR COMPARISONS OF REGRESSIONS $D=a+bB$ IN *Catillicephala lata* (RAYMOND), 1937, AND *C. fowleri* SHAW, 1952

	C. lata	*C. fowleri*
$D=a+bB$	$D=0.658B-0.23$	$D=0.527B+0.21$
N	7	6
r^2	.9469	.9670
$\Sigma(y-\bar{y})^2$	12.0550	4.9600
$\Sigma(x-\bar{x})^2$	27.3722	17.2700

In an identical manner we test for significance by the use of t:

$$t=\frac{0.658-0.527}{0.0847}$$

$$t=1.55$$

Entering the table with:

$$D.f.=N_1+N_2-4=7+6-4=9$$

we find that the probability (P) of obtaining the value $t=1.55$ by chance lies between 0.50 and 0.10. Since P must be no higher than 0.05 to prove significant difference, we must regard the values of b_D as not significantly different in *Catillicephala lata* and *C. fowleri*. This corroborates the qualitative opinion expressed earlier (Shaw, 1952, p. 465). Thus, the comparison of the coefficients of regression, although elaborate, is an extremely useful statistical tool in the study of trilobites.

At the risk of laboring the point we may return to the samples of *Parabolinella triarthroides* mentioned earlier. It has been shown that two samples of 10 specimens taken from opposite ends of the ontogenetic series are significantly different when ratios are used for comparison. As a demonstration of the sensitivity of the comparison of regressions we can take the same two samples, derive their regressions, and compare them. The formulae are:

$A_2=1.281B-0.116$ mm. (for the immature sample)

$A_2=1.399B-0.174$ mm. (for the adult sample)

and computation of σ_{d_b} from original data shows that

$$\sigma_{d_b}=0.158$$

so that:

$$t=\frac{1.399-1.281}{0.158}=\frac{0.118}{0.158}=0.746$$

which, with

$$D.f.=N_1+N_2-4=16$$

gives us

$$P>0.50$$

clear proof that samples at least this divergent could be selected from *P. triarthroides* more than 50% of the time, so that the difference between the coefficient of regression (b) for immature and adult samples is certainly due to chance alone. Comparing this demonstration with the totally false results obtained when ratios were used shows that this statistical method, while more elaborate, is superior to the comparison of ratios when more than one growth stage is involved.

The Standard Error of the Coefficient of Regression (σ_b)

The third complementary statistic that may be calculated is the standard error of the coefficient of regression (σ_b), which is the square root of the quotient of the variance of the regression (S_Y^2) divided by the sum of the squares of the deviations from the mean of the independent variate ($\Sigma[(x-x)^2]$) thus:

$$\sigma_b=\sqrt{\frac{S_Y^2}{\Sigma[(x-\bar{x})^2]}}$$

For *Catillcephala lata* in the situation given in Table 5 (where $K_1=0.815B+0.06$), the formula for the standard error of the coefficient of regression is:

$$\sigma_b=\sqrt{\frac{0.04667}{29.27}}$$

$$=0.1263$$

With this value we may place fiducial limits (l) around the value of b for any probability level we wish (usually 1%), thus:

$$l_1=0.815+(t_{.10})(0.1263)$$

$$l_2=0.815-(t_{.10})(0.1263)$$

where t has N-2 degrees of freedom;

$$l_1=0.815+(1.943)(0.1263)=1.060$$

$$l_2=0.815-(1.943)(0.1263)=\ .570$$

Thus, on the basis of the small sample available we may say that there is only one chance in 100 that the value of b lies outside the limits .570 and 1.060.

Comparison of the coefficient of regression with arbitrarily selected values.—Another use of σ_b is as a rough check on the difference between regressions. Thus, a comparison of the regression $K_1 = a + bB$ in *Catillicephala lata* and *C. fowleri* is:

$$t = \frac{0.815 - 0.965}{0.1263}$$

$$t = 1.188$$

with:

$$D.f. = N_1 + N_2 - 4 = 11$$

This value of t shows (Snedecor, 1946, p. 65) that there is less than a 3% but more than a 2% chance of such a difference existing between the coefficient of regression by chance alone, but since this is a test of the *difference between the coefficients of regression only* and is not a comparison of the entire regressions, the difference between the regressions themselves could not be rejected on the strength of this test alone when the results are so near the level of significance. This test, ignoring as it does the value of a in the regression formula can only be relied upon when highly significant differences appear. As we have seen above, the comparison of regressions demonstrates the significance of the difference between two species in these two variates.

A more frequent comparison is that between b and zero as a test of the significance of the coefficient. This has in effect been accomplished by setting fiducial limits in the case of *C. lata*, but on occasion it may be desirable to make the test without determining the fiducial limits. Thus, for *C. lata*:

$$t = \frac{0.815 - 0.000}{.1263}$$

$$t = 6.453$$

which demonstrates a high degree of significance of the difference of the coefficient of regression from zero. In this case

$$D.f. = N - 2 = 6$$

LIMITATIONS ON STATISTICAL TREATMENT

Non-numerical features.—Some of the characters of the trilobite test are poorly or not at all susceptible to numerical representation, which renders rigorous statistical treatment difficult or impossible. An example of this sort can be found in the gradual obsolescence of the glabellar furrows in *Plicatolina kindlei* Shaw, 1951 (Table 7). In this species the glabellar furrows tend to become obsolete in the middle, but first they pass through a stage in which the furrow is faintly impressed medially. In commenting on the original draft of this paper, Dr. B. H. Burma suggested that such semi-quantitative features may sometimes be adapted to statistical treatment by assigning numerical values to the stages involved; this seems to offer several possibilities for future investiga-

TABLE 7—RECORD OF THE OBSOLESCENCE OF GLABELLAR FURROWS IN *Plicatolina kindlei* SHAW, 1951

No.	Length of Glabella (including occipital ring) in mm.	Glabellar furrow				Location of Specimen
		Anterior	second	third	posterior	
3	1.23	F*	C	C	C	USNM
1	1.28	B	C	C	C	USNM
18	1.97	B	F	C	C	MCZ
15	2.08	B	B	F	C	Kindle
4	2.26	B	F	C	C	Kindle
5	2.50	B	B	F	F	USNM
6	2.72	B	B	B	C	MCZ
16	3.36	B	B	F	F	MCZ
2	3.89	B	B	B	B	USNM
19	4.67	B	B	B	B	USNM

* Symbols: C = Furrow completely mesially. F = Furrow faintly impressed mesially. B = Furrow broken mesially.

tion, for obsolescence of furrows is frequently a feature of trilobite ontogeny.

Another feature that may in the future be treated numerically, but for which I can now see no satisfactory quantitative expression, is ornamentation. Rasetti (1948, p. 9) has noted that in tuberculate species the number of tubercles is variable, but at present ornamentation does not generally play an all-important role in species division, although many genera do show a characteristic ornamental pattern. It may be noted that the statement that ornamentation is of no use in identification because it is not often preserved (Lochman, 1947, p. 61) seems to be indefensible. I do not believe that preservation is relevant to the question of importance. If ornamentation were the character necessary to distinguish one genus or species from another then it would be all-important regardless of preservation, and specimens on which the surface was destroyed would be unidentifiable. Preservation does not govern importance; it only governs usefulness.

The interpretive limitation.—The most effective limitation on the statistical approach to trilobites is the fact that nothing in the data that is accumulated tells the investigator how to interpret his results. A most obvious case in point is provided by *Geragnostus bisectus* (Matthew), 1892, as described from the lower Highgate (erroneously called "upper Gorge") formation of Vermont (Shaw, 1951, pp. 111–112; Shaw, 1955). In *G. bisectus* from Vermont two forms of the cephalon are present; one, a short head with semicircular cheeks, termed *G. bisectus* var. *brevis*, and a longer head with U-shaped cheeks, called *G. bisectus* var. *typica*. There is no apparent separation, either qualitative or quantitative, in the pygidia, such as would permit the erection of separate species, although the pygidia are unusually variable. The critical relationship is that between the sagittal length of the head, from the rear of the glabella to the marginal furrow (X), and the maximum width of the cheeks (Y). The relevant data are given in Table 8 and graphed in Text-fig. 2. A comparison of *G. b.* var. *brevis* with the regression for *G. b.* var. *typica* is made in Table 9. This comparison is like that made for *Parabolinella triarthroides* earlier in this paper.

TABLE 8—RAW DATA FOR *Geragnostus bisectus* (MATTHEW), 1892

Variety *brevis*

Specimen Number	Intramarginal Cephalic Length	Maximum Width of Cheeks	Location of Specimen
5	2.19	2.47	USNM
13	2.22	2.38	C. H. Kindle
7	2.26	*2.47**	MCZ 4885
1	2.40	2.68	USNM (type)

Variety *typica*

Specimen Number	Intramarginal Cephalic Length	Maximum Width of Cheeks	Location of Specimen
2	1.06	*1.06*	———
12	1.27	1.27	MCZ 4884
16	1.55	1.43	MCZ 4882
11	1.73	1.55	C. H. Kindle
10	1.83	*1.98*	C. H. Kindle
4	1.98	1.98	C. H. Kindle
3	2.20	*2.12*	MCZ 4881
8	2.61	*2.40*	C. H. Kindle
6	2.75	2.47	USNM
17	2.90	*2.68*	UW A1003

* Measurements made on one side of specimen and doubled are italicized.

The regression formula for *G. bisectus* var. *typica* is:

$$Y_c = 0.843 + 0.22$$

$$S_Y = 0.112$$

By substituting the observed values of the glabellar length (X) in *G. b.* var. *brevis* in this formula we obtain values of the cheek width (Y_c) which should exist in *G. b.* var. *typica* of this head size if both varieties are identical (Table 9, col. 3). Subtraction of the observed values of *G. b.* var. *brevis* (Table 9, col. 4) gives the deviations (Column 5), which, as a test of significance are divided by the standard error of estimate for *G. b.* var. *typica*, thus:

$$t = \frac{Yc - y}{S_Y}$$

where:

$$D.f. = N_1 + N_2 - 3$$

and:

N_1 = number in sample from which regression was calculated (in this case ten)

TABLE 9—COMPARISON OF *Geragnostus bisectus* VAR. *brevis* WITH *G. bisectus* VAR. *typica*. REGRESSION FORMULA FOR *G. bisectus* VAR. *typica*: $Yc=0.843B+0.22$. $S_Y=0.11$. ALL MEASUREMENTS IN MILLIMETERS. $t=Yc-y/S_Y$ WITH $D.f.=9$

No.	var. *brevis* (X)	Yc	*y*	Yc−*y*	*t*	P	Location of Specimen
5	2.19	2.07	2.47	−0.40	3.57	<0.01	USNM
13	2.22	2.09	2.38	−0.29	2.60	<0.05 >0.02	Kindle
7	2.26	2.13	2.47	−0.34	3.04	<0.02 >0.01	MCZ
1*	2.40	2.24	2.68	−0.44	3.93	<0.01	USNM

* Type specimen of the variety.

$N_2=1$ (the single specimen being compared)

so that:

$$D.f.=N_1-2=8$$

Entering the Table of *t* we find that the $t=3.57$ for Specimen 5 is more than that listed in the column headed 0.01 meaning that there is less than one chance in a hundred for such a value to arise by random chance. We may, therefore, regard Specimen 5 as differing significantly in the maximum cheek width from specimens of *G. b.* var. *typica* with the same intramarginal head length. Comparing the other specimens of *G. b.* var. *brevis* (Table 9, col. 7) shows that in all cases the difference is significant, i.e., $P<0.05$ in all cases.

The difference between these two varieties, thus, seems to be quite clear in a statistical sense, but the interpretation of this difference is difficult indeed. The hypothesis favored here is that these varieties are males and females, the agnostidean equivalent of the *forme large* and *forme longue* of Barrande. It seems unlikely that trilobites were different from other related arthropods in that they wholly lacked sex differentiation, although this is the view, at least by implication, of most students of the group. However, it is possible that *G. b.* var. *brevis* represents a locally developed genetic mutant that was viable but uncommon.

Interpretations that can be discarded are: (1) that the differences are due to compression or to differences of preservation, for the specimens are not crushed or distorted (see Shaw, 1951, pl. 23, Fig. 11); and (2) that the differences are successional in time, since all specimens are from one layer.

Thus, in spite of a quantitatively valid separation between these two groups, the interpretation is still in doubt. Similar dimorphism is shown by *Geragnostus hoeki*, as mentioned by Shaw (1951, p. 11), and by other agnostids observed in the laboratory but not yet subjected to quantitative study. Conversely, however, it is not yet demonstrable that dimorphism exists in all agnostids; the problem requires much study.

LIST OF STATISTICS TO BE COMPUTED FOR ADEQUATE TREATMENT

A large number of statistics is computed in the course of any treatment of a trilobite sample. Many of these statistics have only temporary usefulness in computing others, but some of these intermediate quantities should be recorded so that other students may use them. Following is a recommended minimum list of statistics which should accompany published studies. Naturally, if editorial policy permits, the raw data should also be given.

(1) $Y=a+bX$ for all reasonably comparable variates (an essential article on the selection of "comparable variates" by Miller & Weller (1952) should be prerequisite reading for anyone considering this problem).
(2) *r* for all pairs of variates compared.
(3) level of significance (P) for *r*.
(4) N for all samples.
(5) $\bar{x}$, mean of the independent variables.
(6) $\bar{y}$, mean of the dependent variables.
(7) $\Sigma(x-\bar{x})^2$, the sum of the squares of the deviations of the independent variables from their mean.
(8) $\Sigma(y-\bar{y})^2$, the sum of squares of the dependent variable.

(9) standard error of estimate,

$$S_Y = \sqrt{\frac{(Yc-y)^2}{N-2}}$$

(10) $$\sigma_b = \sqrt{\frac{S_Y^2}{\Sigma(x-\bar{x})^2}}$$

LIST OF STATISTICAL SYMBOLS USED IN THIS ARTICLE

a—intercept on Y axis
b—coefficient of regression (b_1 and b_2 used to distinguish the two coefficients in the pair of formulae $Y=a+bX$ and $X=a+bY$)
$D.f.$—degrees of freedom
l_1, l_2—upper and lower fiducial limits of any variable
N—number of pairs of observations in a paired sample or number of observations in a single sample
r—coefficient of correlation $\sqrt{(b_1)(b_2)}$
X—first variable in a linear regression*
$\bar{x}$—arithmetic mean of first variable
X_c—a value of the variable X derived by substitution in the formula $X=a+bY$
Y—second variable in a linear regression
$\bar{y}$—arithmetic mean of second variable
Y_c—a value of the variable Y derived by substitution in formula $Y=a+bX$
σ—standard deviation of the mean
σ_b—standard error of estimate of the coefficient of regression
σ_{d_b}—standard error of estimate of the difference of two coefficients of correlation
σ_r—standard error of estimate of the coefficient of correlation
σ_z—standard error of estimate of z
Σ—"sum of . . . "
P, t and z—as defined in any standard text

* X and Y are here called "first" and "second" variables rather than the more common "independent" and "dependent" because in most cases it is useful to calculate both formulas $Y=a+bX$ and $X=a+bY$ so that neither variable is truly "independent" or "dependent."

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MANUSCRIPT RECEIVED APRIL 4, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1225–1247, 4 TEXT-FIG., SEPTEMBER 1956

MISSISSIPPIAN MICROCRINOIDS FROM OKLAHOMA AND NEW MEXICO

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ABSTRACT—One new genus, *Lampadosocrinus*, and ten new species, *Allagecrinus sculptus, Kallimorphocrinus angulatus, K. weldenensis, K. tintinabulum, Trophocrinus variabilis, T. bicornis, T. brevis, Tylthocrinus alamogordoensis, Dichostreblocrinus pyriformis*, and *Lampadosocrinus obtusus* are described from the Lake Valley formation of New Mexico and the St. Joe formation and pre-Welden shale of Oklahoma. The validity of the genus *Hybochilocrinus* is examined in the light of new material, and the suggestion is made that it be considered a synonym of *Allagecrinus*. The generic concept of *Kallimorphocrinus* is emended, and *Coencystis moreyi* is placed in synonymy with *Kallimorphocrinus moreyi*. The genus *Amphipsalidocrinus* is discussed, and it is recommended that *Octocrinus* should not be considered as its synonym. The competence of the genus *Octocrinus* is also questioned, and it is suggested that it be accepted as a synonym of *Tylthocrinus*. The species *Dichostreblocrinus minutus* is designated as the genotype of the new genus *Lampadosocrinus*.

INTRODUCTION

FOR several years, the senior author has collected from various sources a number of excellent specimens of microcrinoid calyxes from the Osagean, St. Joe formation of Oklahoma, the Lake Valley formation of New Mexico, and the Kinderhookian?, pre-Welden shale of Oklahoma. The pre-Welden shale is so named by C. L. Cooper (1939, p. 383–384) who considers it to be equivalent to the Bushberg-Hannibal formations of Missouri.

We regard these specimens with special interest, because they not only help to ascertain the regional correlation of the Lake Valley formation of New Mexico with the St. Joe formation of Oklahoma and Fern Glen formation of Missouri, but they also add substantially to our knowledge and understanding of this interesting group of organisms. In recent years, most of the research concerning microcrinoids in North America has been concentrated on Pennsylvanian and Permian forms, and aside from Peck's contributions in 1935 and 1936, an unpublished master's thesis written by Connelly in 1950, and a brief nomenclatural note by Peck & Connelly in 1951 the abundant material present in the Mississippian formations of this continent has been neglected. Prior to 1935, the work concerning North American Mississippian microcrinoids and related forms was done by Shumard (1866), Meek & Worthen (1866, 1868, 1873), Wachsmuth (1882, 1883), Rowley (1895, 1907), Springer (1923), and Kirk (1930). Moore, in 1940, discussed and summarized the information of the various members of the family Allagecrinidae but did not describe any new forms from the Mississippian.

The known distribution of all recorded representatives of microcrinoids and related forms from North America is summarized in Table 1. The fact that there is a blank in our records for specimens from formations of Meramecian age does not necessarily indicate that those formations are barren, but it does appear to denote a lack of interest in recent years in the smaller Mississippian representatives of the Crinoidea. The present study has impressed us with the usefulness of these minute forms as stratigraphic indicators, and we feel that in time, as more knowledge concerning them is accumulated, they will come to rank in importance with other forms of micro-organisms as tools for surface and subsurface correlation.

ACKNOWLEDGMENTS

We wish to acknowledge with thanks the assistance and materials received from the following individuals: Dr. Carl C. Branson, Dr. Edwin Kirk, Dr. Lowell R. Laudon, Dr.

TABLE 1—KNOWN DISTRIBUTION OF NORTH AMERICAN, MISSISSIPPIAN MICROCRINOIDS AND RELATED MEGACRINOIDS
(Authors and dates given for reference only)

Mississippian System
- Chesterian series
  - Pitkin limestone, Oklahoma
    - *Catillocrinus* sp., Laudon, 1941
  - Renault formation, Illinois; Gasper formation, Alabama
    - *Allocatillocrinus carpenteri* Wanner, 1937 = *Catillocrinus carpenteri* Springer, 1923 = *Allagecrinus carpenteri* Wachsmuth, 1882
- Osagean series
  - Burlington limestone, Iowa
    - *Catillocrinus wachsmuthi* Meek & Worthen, 1868a = *Synbathocrinus* (*Nematocrinus*) *wachsmuthi* Meek & Worthen, 1866
  - Fern Glen limestone, Missouri
    - *Kallimorphocrinus moreyi*, Strimple & Koenig, 1956 = *Coencystis moreyi* Peck, 1936
    - *Kallimorphocrinus pristinus* Peck, 1936
    - *Kallimorphocrinus puteatus* Peck, 1936
    - *Lampadosocrinus minutus*, Strimple & Koenig, 1956 = *Dichostreblocrinus minutus* Peck, 1936
    - *Passalocrinus triangularis* Peck, 1936
    - *Trophocrinus corpulentus* Peck, 1936
    - *Tytthocrinus inconsuetus*, Strimple & Koenig, 1956 = *Octocrinus inconsuetus* Peck, 1936
  - Keokuk limestone, Indiana
    - *Catillocrinus shumardi* Springer, 1923
    - *Eucatillocrinus bradleyi* Springer, 1923 = *Catillocrinus bradleyi* Meek & Worthen, 1873, 1868
  - Lake Valley formation, New Mexico
    - *Allagecrinus sculptus*, n. sp.
    - *Dichostreblocrinus pyriformis*, n. sp.
    - *Kallimorphocrinus angulatus*, n. sp.
    - *Lampadosocrinus obtusus*, n. sp.
    - *Passalocrinus triangularis* Peck, 1936 (Strimple & Koenig, 1956)
    - *Tytthocrinus alamogordoensis*, n. sp.
  - New Providence shale, Tennessee and Kentucky
    - *Catillocrinus tennesseeae* (Troost) Shumard, 1866
    - *Catillocrinus turbinatus* Springer, 1923
  - St. Joe formation, Oklahoma
    - *Allagecrinus sculptus*, n. sp.
    - *Kallimorphocrinus angulatus*, n. sp.
    - *Lampadosocrinus minutus*, Strimple & Koenig, 1956 = *Dichostreblocrinus minutus* Peck, 1936
    - *Passalocrinus triangularis* Peck, 1936 (Strimple & Koenig, 1956)
    - *Trophocrinus bicornis*, n. sp.
    - *Trophocrinus brevis*, n. sp.
- Kinderhookian series
  - Chouteau limestone, Missouri
    - *Allagecrinus rowleyi* Peck, 1936 = *Hybochilocrinus rowleyi* Moore, 1940
    - *Trophocrinus exsertus* Peck, 1936
  - Louisiana limestone, Missouri
    - *Allagecrinus americanus* Rowley, 1895 = *Hybochilocrinus americanus* Weller, 1930
  - pre-Welden shale, Oklahoma
    - *Kallimorphocrinus tintinabulum*, n. sp.
    - *Kallimorphocrinus weldenensis*, n. sp.
    - *Passalocrinus triangularis* Peck, 1936 (Strimple & Koenig, 1956)
    - *Trophocrinus tumidus* Kirk, 1930 (Strimple & Koenig, 1956)
    - *Trophocrinus variabilis*, n. sp.

Raymond C. Peck, Dr. Thomas R. Beveridge, Mr. Richard Alexander, Mr. Claud Bronaugh, and Mr. Walter Niewoehner. Mrs. Strimple ably assisted the senior author on his collecting trips, and Mrs. Koenig and Miss Bonnie Wills prepared the typescript. All the illustrations are camera lucida drawings prepared by the junior author.

SYSTEMATIC DESCRIPTIONS

Family ALLAGECRINIDAE Carpenter & Etheridge, 1881, emend. Moore, 1940

Genus ALLAGECRINUS Carpenter & Etheridge, 1881, emend. Wright, 1932

The genus *Allagecrinus* has been well defined by Wright (1952, p. 139) in his monograph on British Carboniferous Crinoidea,

consequently it will suffice to give here only a brief description. There are three cycles of plates in the calyx; three BB which are generally ankylosed into a single unit, five RR, and five OO. The oral plates are not always present on fully mature specimens. The RR of immature forms are approximately equal in width, but upon maturing the RR become decidedly unequal in width with the LAR being narrowest and the AR somewhat wider than the other three. The RPR of mature specimens is differentiated by a sloping left shoulder which drops well below the distal edge of the LPR and supports an arm-like series of anal plates. The RAR, AR, and LPR of mature specimens may be axillary and have two or more arm-bearing, muscular articulation facets. The LAR and right shoulder of the RPR have only one arm-bearing facet apiece in all growth stages. The five OO are nearly equal in size with the PO being the largest and somewhat differently shaped in outline. A node or hydropore? is usually present on the PO through all stages of growth up to early maturity; it may be present, but invisible on older specimens. The arms are simple and unbranched. The column tapers distally from the base of the dorsal cup.

During our preliminary study of the specimens herein described as belonging to a new species of *Allagecrinus*, the question arose concerning their proper generic designation. The reason for this puzzlement was caused by elements of our specimens which were comparable with those of *Hybochilocrinus americanus* (Rowley), 1895 and *H. rowleyi* (Peck), 1936 as well as with those of representative species of *Allagecrinus; A. austinii* Carpenter and Etheridge, 1881 in particular. Since there has been some question in the past (Peck, 1935, 1936, and Wright, 1932, p. 363; 1933, p. 204) concerning the validity of the genus *Hybochilocrinus*, it was thought advisable to reexamine the problem for the purpose of the proper generic designation of our specimens. The results of our inquiry have led us to make the following recommendations: (1) that the genus *Hybochilocrinus* Weller, 1930, be considered as a junior subjective synonym of *Allagecrinus* Carpenter & Etheridge, 1881 emend. Wright, 1932, and (2) that *Allagecrinus americanus* Rowley, 1895 (Weller's genotype of *Hybochilocrinus*) be considered as the oldest known species of the genus *Allagecrinus*. The reasons for these recommendations are as follows:

(1) The material upon which J. Marvin Weller based his diagnosis, by comparison with other collections, was scanty and, by his own admission, in a poor state of preservation. When Weller wrote his report, he stated that he had in his possession "about one hundred specimens collected from the type locality in 1896 by Professor Stuart Weller" (J. M. Weller, 1930, p. 15). In comparison, when Rowley first described the species in 1895 he had "over three hundred specimens of all sizes" in his collection, (Rowley, 1895, p. 219) and again in 1907 when he repeated his original description he said that he had "added several hundred more of these minute organisms" to his collection (Rowley, 1907, p. 68). In 1935, Peck stated that Rowley led him to and pointed out the "locality and horizon from which he (Rowley) obtained the type material" and that "two small samples collected there yielded over 300 well preserved crinoid calyces" (Peck, 1935, p. 766). It is significant to note that Peck did not recognize the genus *Hybochilocrinus* in 1935 when he studied the growth stages of *Allagecrinus americanus* (Peck, 1935, p. 765) or later when he described *A. rowleyi* from the Chouteau and noted its close resemblance to *A. americanus* (Peck, 1936, p. 285). The junior author during the course of this present study has examined 468 specimens of *A. americanus* which were collected from the Louisiana limestone at three different localities in Missouri. The localities and the number of specimens from each are as follows: Town Branch at Louisiana, Missouri—100 specimens; Clinton Springs, Missouri—112 specimens; Clarksville, Missouri—256 specimens. These specimens were collected and generously given to the junior author by Walter Niewoehner of the University of Missouri. The majority of these specimens are in an excellent state of preservation.

As for the physical condition of Weller's specimens, he admits in three different statements in his discussion of the genus and description of the genotype of *Hybochilo-*

crinus that the majority of them were poorly preserved. In discussing the number of arm-bearing facets on the radial plates, he says that "a few rather poorly preserved individuals may possess radials which are axillary, but this cannot be stated as a certainty" (Weller, 1930, p. 13). Again referring to the same topic, he states "the specimens are all highly calcified and many of them apparently more or less worn so that it is difficult to determine their detail structure" (Weller, 1930, p. 14). In his discussion concerning the beveled condition of the upper left-hand corner of the RPR, he states that "the majority of the crinoids, however, are so poorly preserved that its presence or absence cannot be determined with certainty" (Weller, 1930, p. 15).

(2) The study of more than 1000 specimens of *Allagecrinus americanus* by several independent investigators has indicated that the radial plates are axillary, and that a mature calyx may bear as many as nine arm facets. This observation is definitely not in accord with Weller's statement that the genus *Hybochilocrinus* is characterized by occurrence of no more than five arm facets. He states that even though "Rowley reported that in some of his larger specimens the radials are axillary" he (Weller) could not verify the observation and that the "best specimens" which were examined by him were "all comparatively large examples" and "did not possess more than one arm to a radial" (Weller, 1930, p. 14). Moore published two papers in 1940 in which he accepted *Hybochilocrinus* as valid. He specifically notes in one paper that the primary distinction of the genus from *Allagecrinus* "is in the character of the arm facets" and that "none of the radial plates of *Hybochilocrinus* bears more than a single facet and each facet is evidently a simpler structure than in *Allagecrinus*" (Moore, 1940, p. 78). In the other paper, he states that "*Hybochilocrinus* corresponds to *Allagecrinus* in asymmetry of form and in having an anal plate attached to the left shoulder of the rpR, but it is less advanced in that mature calices bear only five arms" (Moore, 1940a, p. 573). It must be remembered that in the two instances when Weller mentioned his observations regarding the number of arm facets developed on mature specimens, that he also observed that most of his less than 100 specimens were at best in a poor state of preservation, and that there was an element of doubt in his observations. With this thought in mind, it seems significant to review the following facts: (1) Rowley (1895, p. 219) notes that the larger examples from his collection of over 300 specimens possess "scars for the attachment of nine arms while the smaller examples have but five facets." (2) Peck (1935, p. 766) after studying "over 300 well preserved crinoid calyces" notes that "on the majority of representatives there is one arm to a radial, but the radials may be axillary." He also did not recognize the genus *Hybochilocrinus* in 1935 or later when he described *Allagecrinus rowleyi* Peck from the Chouteau limestone of Missouri, even though this species is reported to have developed only five arm facets at maturity (Peck, 1936, p. 285). (3) Williams (1945, p. 65) as a disinterested observer reported on the examination of specimens of *Allagecrinus americanus* from Rowley's collecting locality and states that "the smaller individuals have only one radial facet or opening on each radial plate, and it is subcentral. Larger individuals may have two openings on most radial plates, or most radial plates on the single large individual may have one opening and a few others may have two. On one large individual the writer observed eight openings, and one or two additional ones may have been covered with foreign material." (4) Of the 468 specimens of *Allagecrinus americanus* examined by the junior author, 12 specimens possessed more than five arm facets apiece; the maximum number of fully developed facets noted on a specimen being eight. The total height (including OO) of each of these 12 specimens measures from about 1.3 mm. to about 1.7 mm. Specimens which measure less than 1.3 mm. normally possess five arm facets or less. One specimen from the locality at Clinton Spring, Missouri, measures 1.69 mm. in total height and bears a total of eight and a half arm facets; that is, eight fully developed facets and one partly developed facet (See Text-fig. 4–28–31). Another specimen from the Clarksville locality measures 1.59 mm. in total height and possesses a total of seven arm facets.

(3a) In 1930 when Weller reviewed the characteristics of the family *Allagecrinidae* as defined by Carpenter and Etheridge in 1881, he seemed to regard the apparent absence of an oral crown on the mature representatives of the genotype specimens of *Allagecrinus austinii* as being of primary importance in differentiating them from other specimens which were regarded at the time as belonging to the genus (Weller, 1930, p. 10). It is understandable, therefore, that since mature specimens of *A. americanus* normally retain the oral plates, he would regard them as distinct from the genotype material, although he did not directly mention this fact in his discussion of the genus *Hybochilocrinus*. Later work by Wright in 1932, however, revealed that one of the three type specimens of *A. austinii* does possess an oral arch which had collapsed into the interior of the calyx and thus had been overlooked by Carpenter and Etheridge in their orginal analysis. Wright states that "their failure to discover the oral arch has led to a complete misconception in our ideas of the structure of the calyx in the type form" and that "it is perfectly clear from the evidence of this specimen alone that the 'adult' *A. austinii* possessed an oral arch, and the additional specimens since collected only confirm this statement" (Wright, 1932, p. 342).

(3b) Again in his description of the species of *Hybochilocrinus americanus*, Weller notes that on a "very few" of his larger mature specimens there is "a rounded projection extending above the upper surface of the radial [RPR] nearly to the top of the oral crown." He regards this as "a radianal plate" which has "been pushed upward and nearly out of the calyx." Thus, he concludes that his specimens show "no indication of an anal opening" and that the rectum is probably "situated within the oral plates which were capable of being opened during the life of the crinoid" (Weller, 1940, p. 15). Wright, however, brings out the fact that a similar plate in a similar position on the type specimens of the *Allagecrinus austinii* is actually an anal plate which in turn supports an arm-like series of plates. He states that these plates are "anal plates in the sense that they guard the anal opening and probably functioned in directing the faecal stream or in closing over this anal orifice" (Wright, 1932, p. 343). When Peck published his study of the growth stages of *A. americanus* in 1935, he accepted without question the fact that the anal series originates "on the excavated left shoulder of the RPR" (Peck, 1935, p. 766). Thus, in regard to the above mentioned observations made by Wright on the type specimens, it is worth noting his following statement: "With regard to Rowley's *A. americanus*, probably Mr. Weller would not have removed this species into another genus had he been aware of the presence of an oral arch, anal plate, etc., as has been shown here to be typical of *A. austinii*" (Wright, 1932, p. 363).

(4) The one factor which remains for consideration is the structure of the arm facet of *A. americanus* which as Moore points out is simpler than that of the genotype species. The junior author, after making a thorough examination of the specimens of *A. americanus* at his disposal and four specimens of *A. austinii* from Dr. Wright's collection, considers that the simpler structure might be of some importance in specific consideration but hardly warrants generic status with no supporting characteristics. The fact that the structure of the arm facet of *A. americanus* apparently does not exhibit a transverse ridge is believed to be caused by a lack of distal development of the ligament pit or dorsal fossa, otherwise, the structure is essentially similar to that of the type species. This statement is based on the assumption that the thin outer lip surrounding the depression of the muscular fossa and extending directly upward from the radial plates is morphologically the same structure as the transverse ridge in more advanced forms.

ALLAGECRINUS SCULPTUS, n. sp.
Text-fig. 2—1–12

The mature calyx is large in relation to other mature forms of microcrinoids. It is elongate in shape, and the holotype attains a total height of 1.69 mm. and a maximum width of 1.07 mm. The ratio of width to height is 1.58. The basal circlet is small and forms about one-sixth of the total height of the calyx in mature specimens. The basal circlet rises evenly from the stem facet to the union with the RR with only slight expan-

sion. The BB appear to be completely fused, even in young specimens. The RR are the dominant cup plates and form approximately four-sixths of the total height of the calyx in larger specimens. The LPR which is the only axillary radial that has been observed carries two well developed facets. The anal notch is present at an early stage, though it is not always pronounced.

Immature forms are armless, and the RR are of approximately equal width. The five OO form a low dome with the proximal edges almost flush with the distal extremities of the RR. In maturity, the oral dome is proportionately lower, is sharply delineated from the RR, and forms about one-sixth of the calyx height. The PO is differentiated by being larger than the other OO and by possessing a node which is commonly referred to in the literature as a hydropore. In young specimens, the node is in the form of a long, narrow ridge, but in the holotype it is a circular knob which is pierced by a small round aperture. The oral dome has a distinctive appearance which is especially noticeable when mature specimens are viewed from above. The normal curvature of the outer perimeter of each oral is pronouncedly concave and marks the extension of the depressed median portion of the oral.

The entire surface of the calyx is marked by minute pits which are often obscured through abrasion.

Calyx measurements of *Allagecrinus sculptus:*

Figures (Text fig. 2)	Height in mm.	Width in mm.	H/W Ratio
1–2	0.57	0.33	1.73
3–5	1.23	0.77	1.60
6–7	0.80	0.56	1.43
8–9	1.69	1.07	1.58
10–12	0.62	0.46	1.35

Remarks.—This species is more comparable to *Allagecrinus rowleyi* Peck than to other described species. The main differences are found in the relative height of the basal circlet, the ratio of calyx width to height, and in the outline of the oral circlet when viewed from above. In mature specimens of *A. rowleyi*, the basal circlet occupies about one-fourth of the total calyx height, the ratio of width to height is approximately 1.25, and the oral circlet has a pentalobate outline when viewed from above. In mature specimens of *A. sculptus*, the basal circlet occupies about one-sixth of the total calyx height, the ratio of width to height is approximately 1.58, and the regular outline of the five lobes of the oral circlet is interrupted by a concavity in the midsection of each oral plate.

The trivial name *sculptus* was selected because of the distinctive sculptural aspect of the oral plates.

The similarity between specimens from the St. Joe formation of Oklahoma and those from the Lake Valley formation in New Mexico is remarkable.

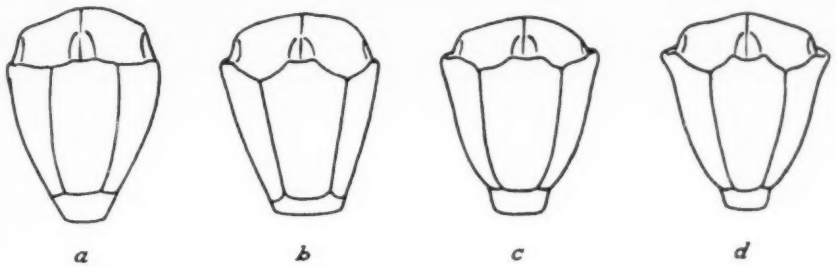
Occurrence.—Nunn member, Lake Valley formation. Wash low in the canyon to the north of Marble canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Thin shale partings between the limestone lentils at the base of St. Joe formation, below the high bluffs of crinoidal limestone overlooking the Illinois River one-quarter mile south of "Eagle's Nest" fishing camp, northeast of Tahlequah, Oklahoma.

Types.—The holotype and several paratypes were taken from shale samples collected by Dr. Carl C. Branson at the Alamogordo locality and several paratypes were taken from samples collected by the senior author at the St. Joe locality. Figured types are to be deposited in the Springer Collection at the U. S. National Museum. Several paratypes are to be deposited in the paleontological collections of the University of Oklahoma.

Genus KALLIMORPHOCRINUS J. M. Weller, 1930

In comparing closely related species of *Kallimorphocrinus*, we have come to the conclusion that the shape of the proximal portion of the dorsal cup is of specific importance. The shape of this portion of the cup is dependent upon the respective shapes and relationships of the basal circlet and the proximal portions of the adjoining RR. For example, the basal circlet of *K. tintinabulum* is relatively narrow at the level of the stem facet, and the sides of the circlet rise almost vertically to the base of the RR which exhibit correspondingly narrow, proximal edges. The rate of expansion of the RR



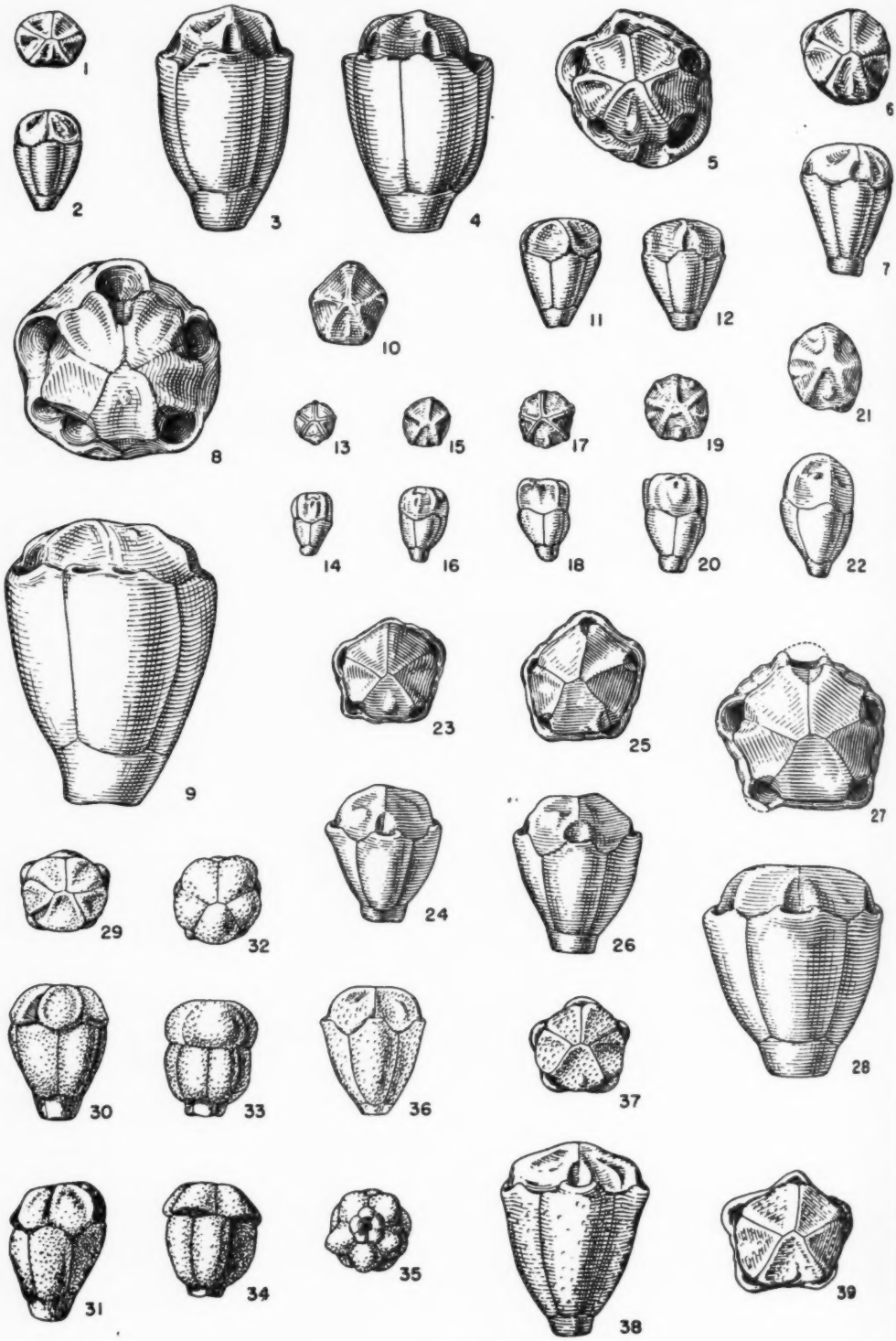
TEXT-FIG. 1—Diagrammatic comparison of (a) *Kallimorphocrinus pristinus;* (b) *K. puteatus;* (c) *K. angulatus;* and (d) *K. tintinabulum.* (1a and 1b after Peck, 1936).

above the junction of the basal and radial circlets is then comparatively rapid (Text-fig. 1d). By comparison, the basal circlet in the dorsal cup of *K. pristinus* also has a comparatively narrow base, but the sides of the circlet widen appreciably as they rise toward the proximal edges of the RR. The lower edges of the radial plates of *K. pristinus* are, therefore, considerably wider than the corresponding portions of the radial plates of *K. tintinabulum* and their distal rate of expansion is relatively less rapid (Text-fig. 1a). In another example, the dorsal cup of *K. angulatus* also possesses a basal circlet which is similar to the basal circlet of *K. pristinus* in having a narrow base, but the sides of which are more erect. The proximal portions of the RR of *K. angulatus* in turn are broad and attain almost full width immediately above the junction of the basal and radial circlets. This broad expansion at the base of the RR thus produces a slight angular break in the surface curvature of the proximal portion of the dorsal cup (Text-fig. 1c). An example of distinct contrast is shown by the basal circlet in the dorsal cup of *K. puteatus.* This circlet is shorter in height than the corresponding circlets of the above-mentioned species, is considerably broader in width, and exhibits nearly vertical sides. The distal rate of expansion of the broad based RR of this species is gradual and nearly uniform throughout (Text-fig. 1b).

Previously published and unpublished descriptions of species of *Kallimorphocrinus* indicate that the basal circlet of the dorsal cup is composed either of an indeterminable number of fused plates or of three plates. In the original description of the genus, Weller (1930, p. 15) describes the basal circlet as a "low disk of anchylosed plates" and nowhere in his paper does he refer to any specific subdivision of the circlet. Our present investigations and Connelly's unpublished researches in 1950 necessitate the emendation of Weller's generic concept of *Kallimorphocrinus* to include those forms which contain five plates in the basal circlet.

Connelly, in an unpublished Master's thesis, University of Missouri (1950, p. 23–26) describes specimens of *Kallimorphocrinus moreyi* (Peck) which were originally referred to as *Coencystis moreyi* Peck (1936, p. 289). Connelly's description indicates that his specimens agree in all respects to Peck's types except that one specimen contains well developed arm facets on the RPR, RAR, and LAR. *Coencystis moreyi* was originally described by Peck as possessing a "small, inconspicuous anal opening" at the "upper right corner of the LPB and the upper left corner of the PB." He assumed a dicyclic arrangement of plates in the dorsal cup with the lowermost circlet possessing five plates. Connelly reexamined Peck's types and concluded that they do not possess any anal plate or opening. From the above stated observations, Connelly concluded that this particular species does not develop arm facets until the calyx reaches a height exceeding 1.5 mm., does not possess an anal opening, and bears a basal circlet composed of five plates. He, therefore, referred the species to *Kallimorphocrinus.* The junior author has also examined Peck's type specimens and he concurs with Connelly's observation.

Under the presently accepted classification, *Kallimorphocrinus* is considered as a member of the family Allagecrinidae which according to its definition includes forms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TEXT-FIG. 2

possessing "5 BB in some, typically 3 or 1" (Moore & Laudon, 1943, p. 30). Therefore, along with our presently described new species of *K. weldenensis* which unquestionably possesses five BB, it seems fitting to emend the original generic definition of *Kallimorphocrinus* to include those forms which possess five BB.

KALLIMORPHOCRINUS ANGULATUS, n. sp.
Text-fig. 1c; Text-fig. 2—13–28

The calyx which is composed of three circlets of plates is stout, subpyriform, and small. A few mature specimens attain a height of approximately 1.2 mm. and a width of 1.0 mm. The basal circlet is low and narrow in relation to the rest of the calyx, occupies about one-tenth the total height, and attains a width one-fourth that of the maximum width of the dorsal cup. The sides of the circlet are almost erect and expand only slightly from the narrow stem facet to the union with the RR. Interbasal sutures have not been observed, thus, the number of plates is unknown. The five RR are dominant features in mature calyxes, and they usually form six-tenths of the total height, but in very immature forms they are more or less subordinate to the oral structure. They are all of relatively uniform width and are broad in relation to their length, being slightly convex both laterally and longitudinally. At its union with the BB, the narrowness of the basal circlet forms a constriction which produces a slight angular break in the surface curvature of the dorsal cup. Immature forms do not exhibit any arm facet development on the RR, but mature individuals bear one facet on each radial plate. No anal structure or opening was observed on any of the specimens examined. The five OO dominate the calyx structure in very immature specimens, but decrease in prominence with approach of maturity. The oral arch of mature forms occupies approximately three-tenths of the total height and thus forms a low, broad, flat dome over the ventral surface of the dorsal cup. The PO is slightly larger than the other OO and bears in the immature stages a prominent tubercle (hydropore?) which becomes less distinct with maturity.

Eight growth stages are figured in Text-fig. 2 illustrating the ontogenetic development of this species; corroborative observations and measurements are listed below:

Stages 1–3: (a) OO are dominant calyx elements; (b) PO possesses a prominent tubercle (hydropore?); (c) Interoral sutures are bounded by prominent raised ridges; (d) No arm facets present on RR.

Stage 4: (a) OO and RR attain parity; (b) Tubercle (hydropore?) on PO still prominent; (c) Raised ridges bounding interoral sutures less prominent; (d) No arm facets present on RR.

Stage 5: (a) OO are prominent, but subordinate calyx elements, the greatest width of calyx now being at upper edges of RR; (b) Tubercle (hydropore?) on PO is less prominent; (c) Raised ridges bounding interoral sutures subdued; (d) Arm facet partially developed on RPR and incipiently developed on LAR.

Stage 6: (a) RR are dominant calyx elements with OO subdued; (b) Tubercle (hydropore?) on PO subdued; (c) Ridges bounding interoral sutures absent; (d) Arm facets developed on RPR, LAR, LPR, and RAR.

Stage 7: (a) OO are further subdued; (b) Tubercle (hydropore?) hardly visible on

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TEXT-FIG. 2—All figures ×25

1–12—Allagecrinus sculptus, n. sp. *1,2*, ventral and lateral (LPR) views of paratype; *3–5*, lateral (RPR), (LAR & LPR), and ventral views of paratype; *6,7*, ventral and lateral (LPR) views of paratype; *8,9*, ventral and lateral (LPR) views of holotype; *10–12*, ventral and lateral (LPR & RPR), (AR) views of paratype.

13–28—Kallimorphocrinus angulatus, n. sp. *13–20*, ventral and lateral (LPR & RPR) views of 4 paratypes; *21–26*, ventral and lateral (RPR) views of 3 paratypes; *27,28*, ventral and lateral (RPR) views of holotype.

29–35—Kallimorphocrinus weldenensis, n. sp. *29–31*, ventral and lateral (LPR & RPR), (AR), views of holotype; *32–35*, ventral, lateral (LPR & RPR), (RAR), and dorsal views of paratype.

36–39—Kallimorphocrinus tintinabulum, n. sp. *36,37*, ventral and lateral (LPR) views of paratype; *38,39*, lateral (LPR) and ventral views of holotype.

PO; (c) Arm facets developed on RPR, LAR, LPR, RAR, and AR.

Stage 8: (a) OO still further subdued; (b) Tubercle (hydropore?) absent; (c) Arm facets developed on RPR, LAR, LPR, RAR, and AR.

Calyx measurements of *Kallimorphocrinus angulatus:*

Growth stages	Figures (Text-fig. 2)	Height in mm.	Width in mm.	H/W Ratio
1	13–14	0.38	0.23	1.65
2	15–16	0.41	0.28	1.46
3	17–18	0.48	0.32	1.50
4	19–20	0.52	0.36	1.44
5	21–22	0.63	0.44	1.43
6	23–24	0.72	0.64	1.13
7	25–26	0.87	0.77	1.13
8	27–28	1.18	1.03	1.14

The information derived from the above observations and measurements can be summarized as follows: The oral dome loses its dominant position in the calyx structure when the arm facets begin to develop on the RR. These arm facets appear first on the RPR, then on the LAR. The facets on the LPR and RAR appear almost at the same time with the LPR developing a little more rapidly than the RAR, and finally a facet appears on the AR. Apparently no more than five arm facets are developed by this species since none of the several dozen large calyxes examined show more than this number of facets. The tubercle (hydropore?) on the PO becomes subdued with the approach of maturity. The ratio of width to height decreases with increase of age until a constant ratio is reached at maturity. After the arm facets are developed, the calyx increases in bulk, but the proportions apparently remain constant.

Remarks.—Specimens representing the species *Kallimorphocrinus angulatus* are relatively abundant in the St. Joe formation of Oklahoma and in the Alamogordo formation of New Mexico. The specimens from the Alamogordo formation are generally more robust than those from the St. Joe formation, but otherwise there is no appreciable difference.

The distinguishing characteristic of this species is the slight, angular indentation of the surface curvature of the dorsal cup at the junction of the basal and radial circlets. In most other respects, specimens of this species exhibit close relationship to specimens of *K. pristinus* Peck and *K. scoticus* (Wright). Minor exceptions to this relationship are that in the former species the height of the basal circlet in relation to the total calyx height is somewhat greater. At comparable growth stages, the ratio of calyx height to width of *K. pristinus* is also somewhat greater than related proportions in *K. angulatus*, thus, *K. pristinus* appears to be more elongate. Specimens of *K. angulatus*, because of the relative flatness of the lateral curvature of the radial plates, exhibit only a very slight depression in the sutural areas between the RR. The dorsal cup, therefore, has a tendency to appear slightly angular or faceted in the radial circlet, whereas the dorsal cup of specimens of *K. pristinus* and *K. scoticus* have a correspondingly more lobate appearance. The outer edge of each oral in *K. scoticus* has an even curvature whereas in *K. angulatus* the mid-portion of each oral is depressed. The nodal protuberance on the PO of *K. scoticus* is more prominent in maturity than in *K. angulatus*.

Occurrence.—Nunn member, Lake Valley formation. Wash low in the canyon to the north of Marble Canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Thin shale partings between the limestone lentils at the base of the St. Joe formation, below the high bluffs of crinoidal limestone overlooking the Illinois River one-quarter mile south of "Eagle's Nest" fishing camp, northeast of Tahlequah, Oklahoma.

Types.—The holotype and numerous paratypes were extracted from samples collected by Dr. Carl C. Branson at the Alamogordo locality. Several paratypes were taken from samples collected by the senior author at the St. Joe locality. Figured types are to be deposited in the Springer Collection at the U. S. National Museum. Several paratypes are to be deposited in the paleontological collections of the University of Oklahoma.

KALLIMORPHOCRINUS WELDENENSIS, n. sp.
Text-fig. 2—29–35

Immature specimens of this species have the appearance of being short and broad, though such a condition is not reflected by the ratio of width to height which is about 1.4. The five BB rise vertically from their

narrow base and are sharply delineated from the five RR. The five OO are prominent and overhang the dorsal cup. In more mature specimens, the BB expand slightly and meet the RR without any decided, angular break. The RR are thus wider at their base in the more mature specimens. In the figured holotype, although the OO are still prominent, they do not overhang the dorsal cup and do not dominate the dorsal cup as they do in younger specimens. The holotype apparently is also an immature form because it does not possess any facets on the radial plates.

In the holotype, there is a peculiar gap between the PO and the LPO. This particular feature was not observed in other specimens of the species, but Peck (1936, pl. 46, fig. 12) figured a similar feature in the holotype of *Kallimorphocrinus moreyi* (Peck). There is still some question in our mind as to whether this is a functional feature.

No anal opening was observed in the outer walls of any of the dorsal cups examined. The entire surface of the calyx is pustulose.

The figured paratype has a height of 0.66 mm., a width of 0.49 mm., and a H/W ratio of 1.40. The figured holotype has a height of 0.76 mm., a width of 0.51 mm., and a H/W ratio of 1.50.

Remarks.—*Kallimorphocrinus weldenensis* is comparable to *K. moreyi* (Peck) from which it differs in having more pronounced ornamentation and in lacking the diamond-shaped interoral areas found in that species.

Occurrence.—Shale bed immediately below the main ledge of the Welden limestone formation in a railroad cut south of Ada, Oklahoma; sec. 27, T. 3 N., R. 6 E.

Types.—The specimens were collected by the senior author. The figured holotype and paratype are to be deposited in the Springer Collection at the U. S. National Museum. A paratype is to be deposited in the paleontological collections of the University of Oklahoma.

KALLIMORPHOCRINUS TINTINABULUM, n. sp.
Text-fig. 1d; Text-fig. 2—36–39

This species is the most common representative of the genus *Kallimorphocrinus* in the pre-Welden shale at the collecting locality and is distinguished by its elongated bell-shaped dorsal cup. The basal circlet is very narrow in relation to the maximum diameter of the cup, and the sides of the circlet rise almost vertically from the stem facet to the base of the RR which have narrow proximal edges. The RR expand rapidly in width to about the midpoint of the cup. At this point the rate of expansion decreases and the subsequent widening of the plates is more gradual. This particular development of the RR, together with the outward flaring surface curvature of their distal extremities, produces the distinctive bell shape of the dorsal cup. Fully mature specimens bear a single arm facet on each radial plate.

The holotype has a height of 1.11 mm., a width of 0.77 mm., and a H/W ratio of 1.44. The oral circlet is relatively low in mature specimens, and the tubercle (hydropore?) on the PO is present in all specimens examined but is not pronounced. Young specimens are distinctive in that the lower extremities of the OO in the interradial areas extend well below the uppermost limits of the RR.

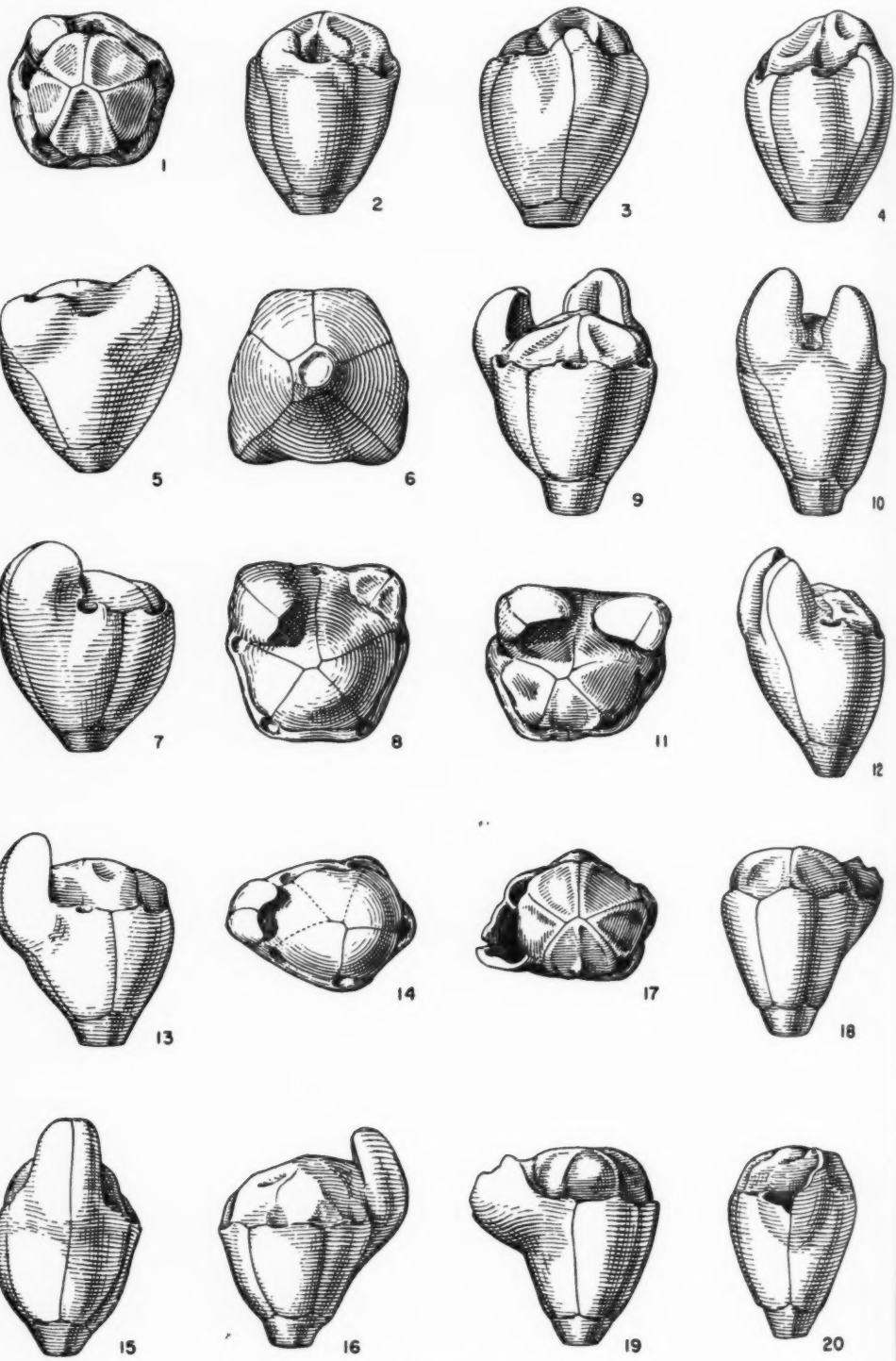
Remarks.—The trivial name is a noun in apposition and is taken from the latin noun meaning "a bell of diminutive size." *K. tintinabulum* is comparable to *K. elongatus* (Wright) even in the pitted nature of its surface. The bell shape of *K. tintinabulum* is more pronounced because of the relatively narrow basal circlet and corresponding decreased width of the lower portions of the radial plates.

Occurrence.—Shale bed immediately below the main ledge of the Welden limestone formation in a railroad cut south of Ada, Oklahoma; sec. 27, T. 3 N., R. 6 E.

Types.—The specimens were collected by the senior author. The holotype and several paratypes are to be deposited in the Springer Collection at the U. S. National Museum. Several paratypes are to be deposited in the paleontological collections of the University of Oklahoma.

Genus TROPHOCRINUS Kirk, 1930

We have concluded from available evidence that the genus *Trophocrinus* Kirk is intimately related to *Kallimorphocrinus* Weller, but that it differs in possessing single or double marginal extensions of the RR. This extraordinary hypertrophy of the



TEXT-FIG. 3

RR is so distinctive and unique among known crinoids that we believe generic segregation is warranted. It is unlikely that sporadic mutation could have produced so many similar forms of such wide geologic and geographic range.

Kirk (1930, p. 211) conjectured that the marginal extensions might represent the "brood pouch" of a sexually dimorphic type. Peck (1936, p. 286), however, did not support Kirk's concept because he considered the evidence "not entirely conclusive." With the present discovery of a form having two marginal extensions, the "brood pouch" concept is further discounted. We are inclined to believe that these marginal extensions represent an effort to obtain an adequate food supply, though we are unable to understand their exact function. One must suppose that at least until adequate arm appendages were developed, the OO in some forms opened sufficiently to admit the passage of food bearing water into subtegmental food gathering processes. It is possible that in this form the marginal extensions represent primitive food gathering devices which served as current deflectors to create a small backwash over the OO, until such time as the brachials were developed. This idea seems to be supported by the reduction in size of the marginal appendage and the full development of the arm facets on the holotype of *Trophocrinus variabilis*.

It is interesting to note that *Trophocrinus* has not been observed in the New Mexico material considered in this study.

TROPHOCRINUS VARIABILIS, n. sp.
Text-fig. 3—1–4

The holotype of this species is represented by a well preserved, robust, subglobular-shaped calyx which has a height of 1.18 mm., a width of 0.97 mm., and a H/W ratio of 1.20. The basal circlet is broad and short and occupies about one-tenth of the total height of the calyx. It expands upward at a moderate rate and joins the proximal edges of the RR with no apparent interruption of the smooth surface curvature of the dorsal cup. The RR are comparatively broad in relation to their length which is about seven-tenths that of the total calyx height. Each radial plate bears a well developed arm facet. The left shoulder of the LAR and the right shoulder of the AR expand outward and upward and mutually form an underdeveloped, marginal, pouch-like extension which rests against the LAO. The five OO are moderately prominent and possess gently concave surfaces at their midsections. The PO is slightly larger and differently shaped than the other OO and is marked by a well developed node (hydropore?). No anal opening or plate was observed.

Remarks.—The unique position of the pouch-like swelling which is formed by the hypertrophic extension of the adjacent halves of the LAR and AR distinguishes this species from all others related to it. Other species of *Trophocrinus* either have this marginal extension developed by the adjacent parts of the LPR and LAR as in *Trophocrinus tumidus*, or by the adjacent parts of the RPR, LPR, and LAR as in *T. bicornis*. Aside from this extension of the RR, *T. variabilis* is similar in all respects to forms assigned to *Kallimorphocrinus*, and it resembles closely *Trophocrinus corpulentus*, from the Fern Glen of Missouri, in size and shape.

In 1936, Peck noted and figured a specimen from the Chouteau limestone of Missouri that has an apparently damaged marginal extension of the adjacent halves of the LAR and AR. Peck (1936, p. 286; pl. 47. fig. 13,14) assigned the specimen to the species *T. exsertus*. This specimen is similar in many respects to *T. variabilis* and may be considered as conspecific with it.

Trophocrinus variabilis is readily dis-

TEXT-FIG. 3—All figures ×25

1–4—Trophocrinus variabilis, n. sp. Ventral and lateral (LAR), (AR & LAR), (AR) views of holotype.
5–12—Trophocrinus bicornis, n. sp. *5–8*, lateral (LPR), dorsal, lateral (RPR & RAR), and ventral views of paratype; *9–12*, lateral (RAR), (LPR), ventral, and lateral (RPR) views of holotype.
13–16—Trophocrinus brevis, n. sp. Lateral (LPR & RPR), ventral, and lateral (LAR & LPR), (AR) views of holotype.
17–20—Trophocrinus tumidus Kirk. Ventral and lateral (AR), (LPR & RPR), (LAR & LPR) views of topotype.

tinguished from associated specimens of the genotype *T. tumidus*—a specimen of which is figured in Text-fig. 3—17–20 for comparative purposes—because it is more robust, has wider RR in comparison to length, and has a smoother surface curvature at the conjunction of the basal and radial circlets. The basal circlet of *T. tumidus* is narrower and longer than the corresponding circlet of *T. variabilis*, and its union with the RR which are rather narrow and elongate is marked by a slight indentation of the surface curvature in that region of the dorsal cup.

Occurrence.—Shale bed immediately below the main ledge of the Welden limestone formation in a railroad cut south of Ada, Oklahoma; sec. 27, T. 3 N., R. 6 E.

Types.—The holotype was collected by the senior author and is to be deposited in the Springer Collection at the U. S. National Museum.

TROPHOCRINUS BICORNIS, n. sp.
Text-fig. 3—5–12

This unique species is represented in our collection by two fairly well preserved specimens. The height of the paratype calyx, excluding the hypertrophic extensions which are slightly worn, is 0.97 mm. The width of this calyx is also 0.97 mm., thus, it has a H/W ratio of 1.0. The holotype calyx is longer and more slender, but it shows evidence of slight lateral compression. It has a height of 1.13 mm., a width of 0.87 mm., and a H/W ratio of 1.30. The shape of the calyx is subpyriform and has a moderate rate of expansion. The basal circlet of the holotype which is in a better state of preservation than the paratype expands upward from a moderately narrow base to a smooth union with the proximal edges of the RR. It occupies a little less than two-tenths the height of the calyx. The basal circlets of both specimens show no indication of sutures, thus, they are considered ankylosed units. The RR are distally quite broad, expand with moderate rapidity from narrow bases, and occupy about six-tenths of the total calyx height. The LPR is abnormally expanded laterally in its upper part because of the hypertrophic expansion and extension of both shoulders on either side of the arm facet. Adjacent parts of the adjoining RPR and LAR are similarly extended, and this relationship produces dual, scoop-like processes which overhang the PO and LPO respectively. The oral crown is a low and subordinate calyx feature. Each of the five oral plates is moderately concave in mid-portion, and the PO is slightly larger than the other OO. There is no observed evidence of a node (hydropore?) on the PO.

Remarks.—The dual marginal extensions of this species serve to distinguish it from all other known forms. However, in general appearance and corresponding proportions, it resembles *Trophocrinus corpulentus* Peck from the Fern Glen formation of Missouri. There may be a closer relationship between these two forms than is apparent from the presently available material because Peck (1936, p. 287) based his definition of *T. corpulentus* on a single immature specimen which has a badly broken marginal extension, and our collections have yielded only two fully mature specimens. Additional specimens will undoubtedly add materially to our sparse knowledge of this very interesting species.

Occurrence.—Thin shale partings between the thin limestone lentils at the base of the St. Joe formation below the high bluffs of crinoidal limestone overlooking the Illinois River, one-quarter mile south of "Eagle's Nest" fishing camp northeast of Tahlequah, Oklahoma.

Types.—The figured holotype and paratype were collected by the senior author and are to be deposited in the Springer Collection at the U. S. National Museum.

TROPHOCRINUS BREVIS, n. sp.
Text-fig. 3—13–16

This form is comparatively broad and robust, possesses a high oral crown, and is subpyriform. The calyx of the holotype has a total height (exclusive of the marginal extension) of 1.0 mm., a width of 0.74 mm., and a H/W ratio of 1.35. The basal circlet is narrow and joins smoothly with the proximal edges of the RR. The plates of the circlet are evidently fused because no sutures are discernible. The basal circlet occupies a little less than two-tenths of the height of the calyx. The RR are broad and fairly uniform in width throughout their length. Their rate of expansion is moderate, and they oc-

cupy about five-tenths of the calyx height. Each radial plate bears an arm facet, and the LPR and LAR are marked by a pouch-like expansion and extension of their adjacent margins. This marginal extension overhangs the LPO and forms a scoop-like process. The five oral plates are subequal in size. The PO which is slightly larger and differently shaped than the other four bears no indication of a node (hydropore?). The plates are smoothly convex with only a faint tendency to be concave in the mid-portion, and together they form a fairly smooth, hemispherical dome over the ventral part of the dorsal cup.

Remarks.—*Trophocrinus brevis* is similar to *T. exsertus* from the lower Chouteau of Missouri, but it differs in having a higher oral crown in relation to the dorsal cup. The oral plates are not as concave, and the PO is not marked by a node. The species is relatively shorter and stouter than *T. tumidus* and its marginal extension is leaner and not quite as bulbous.

Occurrence.—Thin shale partings between the thin limestone lentils at the base of the St. Joe formation below the high bluffs of crinoidal limestone overlooking the Illinois River, one-quarter mile south of "Eagle's Nest" fishing camp, northeast of Tahlequah, Oklahoma.

Types.—The holotype was collected by the senior author and is to be deposited in the Springer Collection at the U. S. National Museum.

Family CODIACRINIDAE Bather, 1899
Genus AMPHIPSALIDOCRINUS Weller, 1930

The genus *Amphipsalidocrinus* was proposed by Weller (1930, p. 33) with *A. scissurus* from the lower Pennsylvanian of Indiana as the genotype species. The holotype was the only known specimen of the genus at that time. Weller tentatively considers the specimen to be a dicyclic form which possesses an infrabasal disc, five BB, five RR, and five OO. On this basis, he is able to compare his specimen with the dicyclic *Cranocrinus* Wanner and *Tenagocrinus* Wanner. Both are Permian genera from the island of Timor.

Peck & Connelly (1951, p. 414) describe another specimen of the genus from the Fern Glen formation of Missouri. The specimen is excellently preserved and is somewhat larger than Weller's specimen. They refer their specimen to *Octocrinus inconsuetus* Peck as a "mature" representative of that species and regard the genus *Octocrinus* as a synonym of *Amphipsalidocrinus*.

Peck & Connelly's "mature" specimen is not specifically described in the text of their note, and no formal attempt is made by them to emend the definition of the genus *Amphipsalidocrinus*, but the emendation is inferred by the illustrations and the statement to the effect that the genus is interpreted as a monocyclic form (Peck & Connelly, 1951, fig. 1–8 and p. 415). They, thus, not only modify Weller's concept of the genus by excluding the infrabasal circlet, but they also reduce the number of BB from five to three. The excellent preservation of Peck's and Connelly's specimen leaves little room for speculation as to the number of BB and their re-examination of the Weller's holotype confirmed that it too possesses three BB, but we do not hold with their interpretation of the genus as monocyclic, because it is entirely possible that the infrabasal circlet composed of IBB is not visible in the known material of two mature specimens. It is not uncommon among known crinoids for the proximal circlet of plates to disappear through fusion or atrophy or to be hidden externally. There is in fact a closely related instance in *Catillocrinus tennesseeae* (Troost) Shumard as illustrated by Springer (1923, pl. 2, fig. 1–2) where the IBB are not recognizable externally but are plainly visible internally.

An important point of similarity between the two specimens which Peck & Connelly fail to mention in their note and which Connelly does not stress in his thesis is the shape and situation of the anal. The illustration of Peck's and Connelly's specimen does not accurately portray the peculiar, lip-like shape of the outer edge of the anal opening, nor does it show that opening in its proper position on the left shoulder of the RPR just below the arm facet (Peck & Connelly, 1951, fig. 1). Connelly (1950, p. 36) notes the position of the anal in his original description of the specimen as follows: "RPR asymmetrical and somewhat larger than the other four, its left shoulder extended to the left to form the outer rim of the anal opening."

This observation is important because Weller (1930, p. 34) describes a similar structure in a similar position on his holotype specimen of *Amphipsalidocrinus scissurus* as follows: "The anal opening is situated slightly below the level of the right posterior arm facet and much nearer this than the left posterior facet. It is very small but rendered conspicuous by a curved outstanding lip which occurs beneath it."

Because of the above stated similarities, in addition to the close relationship of the general proportions and arrangement of the same number of plates of both specimens, we consider the "mature" specimen of Peck & Connelly as a bona fide representative of *Amphipsalidocrinus* as emended. We feel, however, that there are sufficient variations to warrant specification of Peck's and Connelly's specimen, and we shall give our reasons for our rejection of their thesis that *Octocrinus* is a synonym of *Amphipsalidocrinus* in our discussion of the genus *Tytthocrinus*.

Genus Tytthocrinus Weller, 1930

Weller (1930, p. 35) proposed the genus *Tytthocrinus* and based his definition on the genotype and only known species *Tytthocrinus comptus* from the lower Pennsylvanian of Indiana. About 40 specimens of the species were reported. Weller (1930, text-fig. 7) interprets the calyx to be composed of a low infrabasal circlet, five BB, and five large OO. In his description, he notes the uncertainty of this interpretation as to the number and arrangement of the plates (Weller, 1930, p. 35).

Peck & Connelly (1951, p. 415) after re-examining Weller's specimens report that in some of the paratypes three sutures are visible extending outward from the stem facet. On one of the specimens, they note that the sutures extend to the proximal edges of the OO. In other words, they report the presence of only two cycles of plates which they consider to be three BB and five OO. They also noted that the position of the anal opening is strongly displaced to a position just beneath the lower right side of the PO (Peck & Connelly, 1951, p. 414, fig. 7, 8). Thus, Peck & Connelly have established the congeneric relationship between *T. comptus* and *Octocrinus inconsuetus* which is defined by Peck as having three BB, five OO and an anal opening situated "just below the right side of the posterior oral" (Peck, 1936, p. 291). However, Peck & Connelly (1951, p. 415) refer *O. inconsuetus* to *Amphipsalidocrinus* on the premise that Peck's definition of *Octocrinus* was based on immature specimens and that their "mature" specimen is a truer representative. We consider that premise to be untenable for the following reasons:

(1) To our knowledge, there is no precedent for assuming that essential calyx elements as the RR can develop after the calyx has attained rigidity. We are cognizant of such an occurrence in the larval stages of some recent crinoids; e.g., *Promachocrinus* of which it is reported by Clark (1915, p. 332) that BB and OO are present before the appearance of the RR and anal. However, in such stages the plates are little more than expanded, sieve-like films. The formation of fully developed RR, where none previously existed, would be quite a lengthy process, and intermediate stages are to be expected. Peck & Connelly did not observe any such intermediate stages in either their specimens or Weller's. We have found in the material studied by us several specimens which agree very well with Peck's description of *Octocrinus inconsuetus*, but in none of these have we observed any indication of the existence of either incipient or fully developed plates in the position occupied by the RR of *Amphipsalidocrinus*.

(2) A critical examination of the illustrations in Peck's and Connelly's nomenclatural note brings out the interesting fact that the holotypes of both *Octocrinus inconsuetus* Peck and *Amphipsalidocrinus scissurus* Weller are nearly equal in size (Peck & Connelly, 1951, fig. 3,4 and 5,6, respectively). In fact, the holotype of *Octocrinus inconsuetus* Peck is 0.66 mm. in height, and the holotype of *Amphipsalidocrinus scissurus* Weller is 0.63 mm. in height. Extensive studies by Peck (1935), Moore (1940a), Wright (1952), and the present authors has shown that the development of arm facets on the radial plates of all microcrinoids parallels the growth and development of the entire calyx structure. In other words, as the calyx structure increases in size and approaches maturity, the radial plates also develop and with their de-

velopment the facets which bear the arm appendages appear in regular succession, starting with the appearance of a facet on the RPR and finishing with a facet or facets on each of the radial plates. The obvious question thus arises, as to why the holotype of *Octocrinus inconsuetus* should be barren of RR when the holotype of *Amphipsalidocrinus scissurus* which is essentially the same size has five fully developed RR with fully developed arm facets, if the two specimens are as closely related as Peck & Connelly claim.

Even if the smaller size of the holotype of *O. inconsuetus* is considered in relation to the size of Peck's and Connelly's fully "mature" specimen, as a consequence of the former specimen's "immaturity," it still is large enough for us to expect the appearance of at least one radial plate somewhere in the calyx structure. The same argument can be put forward in the case of the relative sizes of the holotypes of *A. scissurus* and *Tytthocrinus comptus* Weller. In either case of the smaller specimens, there has been no report of the appearance of radial plates. In our study, we have not observed any specimens referable to the genus *Amphipsalidocrinus*, and our largest specimen of *Tytthocrinus* is 0.64 mm. in height, or equivalent in size to Weller's holotype.

(3) The anal opening in both *Tytthocrinus* and *Octocrinus* is strongly displaced to the right side of the PO and is situated between the basal and oral circlets. It is difficult for us to visualize its migration to the left shoulder of the RPR as found in *Amphipsalidocrinus*.

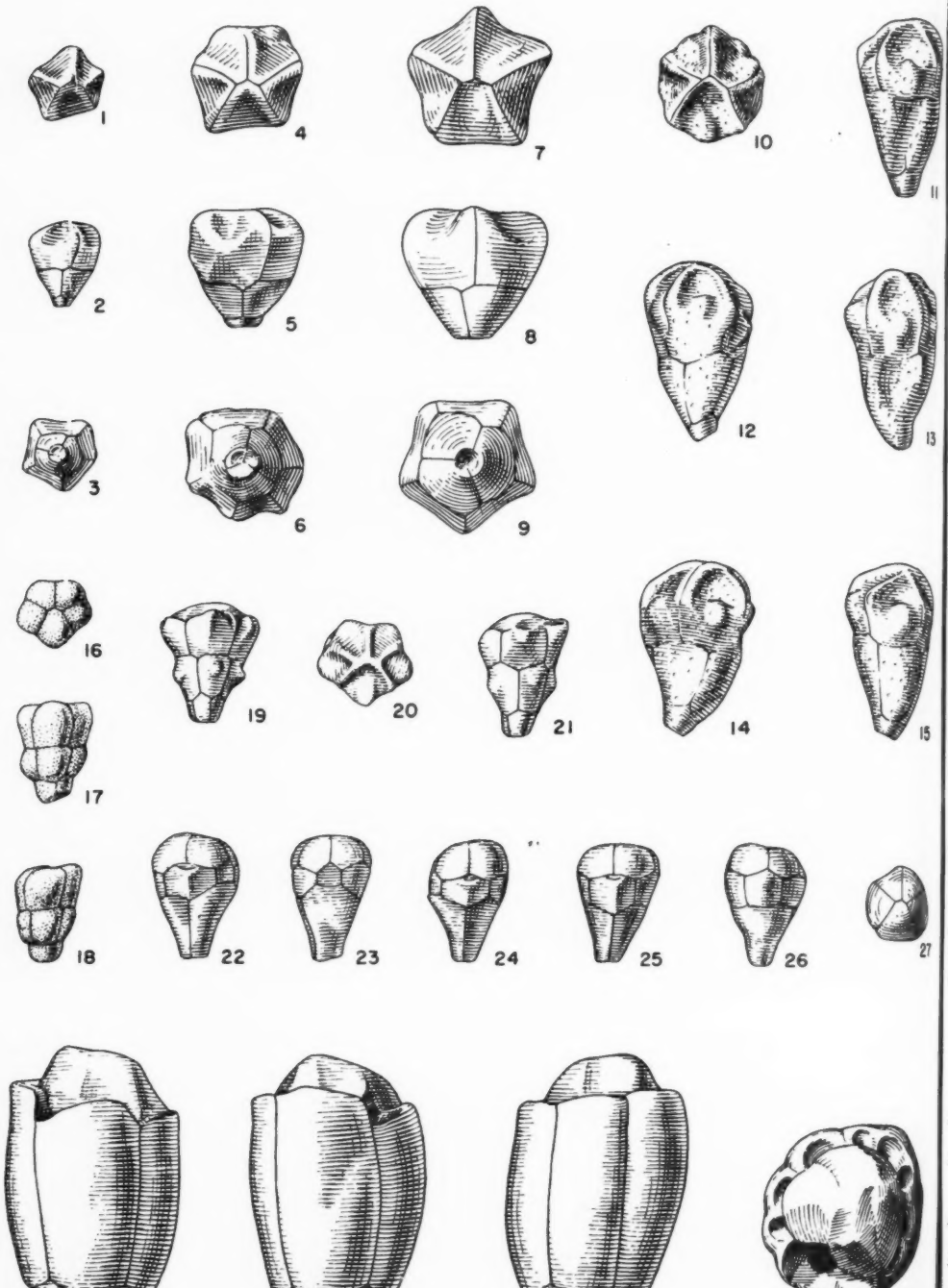
Since the anal opening of *Tytthocrinus* occupies the space between the upper right shoulder of the LPB and upper left shoulder of the RPB—the same position where the RPR appears in *Amphipsalidocrinus*—one is hard pressed to visualize the subsequent development of a radial plate in such a position.

(4) Two immature specimens of *Tytthocrinus alamogordoensis* (Text-fig. 4—3,6) appear to possess small infrabasal circlets each of which is marked by three faint sutures. This occurrence agrees with Weller's observations of a similar circlet in some of his specimens of *T. comptus* (Weller, 1930, p. 35). The larger holotype does not possess this infrabasal circlet. It is possible that the circlet disappears upon maturity either through fusion, migration to the interior of the dorsal cup, or atrophy. As mentioned, there are known precedents for such occurrences: e.g., among fossil crinoids, the axial canals of *Apiocrinus radialus* Eichwald show that the proximal circlet of plates has disappeared through atrophy, and among recent crinoids the proximal circlet found in embryonic stages of *Antedon* disappears with maturity (Bather 1900, p. 125).

The above considerations have led us to recommend that the genus *Octocrinus* Peck be regarded as junior synonym of *Tytthocrinus* Weller, and that on the basis of the present study and on Peck's and Connelly's studies of the type material that the definition of *Tytthocrinus* be emended so that it is regarded as a form which possesses three IBB, three BB instead of five, and five OO.

TYTTHOCRINUS ALAMOGORDOENSIS, n. sp.
Text-fig. 4—1–9

The calyx of this species is conical in shape and it expands rapidly and smoothly from a small stem facet to the flat, ventral surface of the oral circlet. Maximum expansion is reached a little below the upper extremity of the OO. Mature forms are broader than high. The holotype measures 0.72 mm. in width and 0.64 mm. in height. This gives a H/W ratio of 0.9. The proportions of immature forms are directly opposed, being less broad than high, and intermediate growth stages approach H/W ratios of 1.0. The calyx is considered by the authors to be composed of three circlets of plates which consist of three IBB, three BB, and five OO. Mature forms do not retain a distinguishable infrabasal circlet. It is believed that this circlet disappears in the early stages of growth either through fusion, migration to the interior of the dorsal cup, or atrophy. This opinion is based on the observation of a small, flat circlet marked by three faint sutures at the proximal extremity of the calyxes of two immature specimens of *Tytthocrinus alamogordoensis*. J. M. Weller (1930, p. 35) in his original description of the genotype also recognized the presence of an infrabasal circlet, but he modified his remarks by saying that "the arrangement and number of plates is not certainly known because of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TEXT-FIG. 4

the indistinct sutures separating them." The three BB are comparatively large and compose a little less than one-half of the calyx structure. Two of the interbasal sutures are situated beneath the approximate midpoints of the LPO and RAO respectively, and one is beneath the right side of the PO. A notch at the upper extremity of the latter interbasal suture marks the position of the anal. The OO are large and dominate the calyx structure in all stages of growth and constitute a little more than one-half of the calyx height. They rise evenly from their point of contact with the BB, curve inward at the position of maximum expansion, and cover the ventral position of the calyx with slightly concave surfaces. The raised outer borders of the OO are not pronounced, but they give the calyx a pentagonal outline when it is viewed from above or below.

Remarks.—It is pointed out in the discussion of the genus that this species closely resembles *T. inconsuetus* (Peck) in size, shape, and proportions, but differs enough in details to warrant specific identification. The interoral ridges formed by the upturned edges of the OO of *T. alamogordoensis* are not as pronounced as those in *T. inconsuetus*. Also, the inverted, cone-shaped calyx of the new species is somewhat more accentuated in that the width of the truncated proximal portion of the BB is narrower than that of *T. inconsuetus*. The new species can also be distinguished from the genotype, *T. comptus* Weller, by its conical shape, flat ventral surface, and proportionately larger BB. *T. comptus* is more squat and subquadrate in overall shape and its dome which is formed by the ventral portion of the OO is arched, and its BB form about one-third the height of the calyx.

Occurrence.—Nunn member, Lake Valley formation. Wash low in the canyon to the north of Marble canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Types.—The holotype and several paratypes were extracted from shale samples collected by Dr. Carl C. Branson. Figured types are to be deposited in the Springer Collection at the U. S. National Museum. Several paratypes are to be deposited in the paleontological collections of the University of Oklahoma.

Genus DICHOSTREBLOCRINUS Weller, 1930

DICHOSTREBLOCRINUS PYRIFORMIS, n. sp.

Text-fig. 4—10–15

The calyx of this form is slightly twisted and subpyriform to subconical. The height of the holotype calyx is 0.9 mm., and the maximum width is 0.6 mm. The ratio of width to height is 1.5. The infrabasal circlet is small. Its total height is about 0.1 mm., and the number of plates are indistinguishable. The five BB are fairly uniform in size and shape and are longer than wide. They form a little less than half the height of the calyx. They are slightly convex longitudinally, and the axis of the convexity extends from the lower left-hand portion of the plates to the upper right-hand portion, thus giving a slightly counter-clockwise twist to the calyx. The plates are also slightly convex laterally. A cross section in the region of the basal plates possesses a subpentagonal outline. There is no anal opening visible in the posterior region of the dorsal cup.

TEXT-FIG. 4—All figures ×25

1–9—Tylthocrinus alamogordoensis, n. sp. *1–6*, ventral, lateral (posterior interradius), and dorsal views of two paratypes; *7–9* ventral, lateral (posterior interradius), and dorsal views of holotype.

10–15—Dichostreblocrinus pyriformis, n. sp. *10*, ventral view; *11–15* lateral views; *11* (left anterior interradius), *12* (left posterior interradius), *13* (posterior interradius), *14* (right anterior interradius), *15* (right posterior interradius) of holotype.

16–18—Lampadosocrinus obtusus, n. sp. *16*, ventral view; *17,18*, lateral views; *17* (posterior interradius), *18* (left posterior interradius) of holotype.

19–21—Lampadosocrinus minutus (Peck). *19*, lateral view (posterior interradius), *20*, ventral view, *21*, lateral view (left posterior interradius) of homeotype.

22–27—Passalocrinus triangularis Peck. Lateral views (LPR), (RPR), (RAR), (AR), (LAR), and ventral view of homeotype.

28–31—Allagecrinus americanus Rowley. Lateral views (RPR), (LPR), (LAR), and ventral view of homeotype.

Five large oral plates form a dome which occupies about one half the total height of the calyx. The OO are subequal in size, and the PO is slightly larger than the other four and is shaped somewhat differently. The OO rise vertically from their contact with the distal edges of the RR for more than half their length, they then bend inward abruptly to form a slightly convex summit of the calyx. The OO are medially depressed at the summit with sharply turned up margins. The medial depressions slope outward toward the perimeters of the oral plates and, there, swell into rather prominent knobs. This swelling or tubercle on the PO is slightly larger and more prominent than the swellings on the other OO.

Remarks.—This species is similar to *Lampadosocrinus minutus* (Peck) in size and general shape, but it can be distinguished from Peck's specimens by its twisted calyx and more pronounced OO. The anal vent, if present on the upper right-hand edge of the PB, is indiscernible on the figured specimen. It is quite possible that this specimen is immature, and that the anal has not yet developed. This assumption is based on statements made by Weller regarding the genotype species, *D. scrobiculus*. Weller observed that of all the specimens which he regarded as belonging to the species *D. scrobiculus*, only the two largest specimens showed "the lateral anal opening" (Weller, 1930, p. 38). Weller's holotype had a total height of 1.78 mm.

Occurrence.—Nunn member, Lake Valley formation. Wash low in the canyon to the north of Marble Canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Type.—The holotype was extracted from a shale sample collected by Dr. Carl C. Branson. It is to be deposited in the Springer Collection at the U. S. National Museum.

Genus LAMPADOSOCRINUS, n. gen.
Genotype: *Dichostreblocrinus minutus* Peck, 1936

This form consists of three circlets of plates which are composed of five IBB, five BB and five OO. Apparently there are no radial plates developed. In the genotype species, there is a deeply excavated notch between the upper right-hand shoulder of the PB and the upper left-hand shoulder of RPB. In early maturity, this notch is occupied by what appears to be a minute anal plate. If the RR were present, this plate would be in the position normally occupied by the radianal. Presence of a column is indicated by the columnar cicatrix on the base of the infrabasal circlet. The BB are prominent, longer than wide, and each possesses a pronounced protrusion or node in mid-position. This feature is not included in the original description of the genotype, but re-examination of Peck's holotype, and the fact that the feature has been observed on several specimens from the St. Joe locality in Oklahoma confirms its presence. There is no noticeable twisting or distortion of the axial alignment of the BB.

The OO form an unusually high, broad dome with an almost flat ventral surface. On the summit, the OO are concave with slightly raised borders, and the concavity of each oral grades outward into a distinct swelling or knob that gives the species a distinct pentagonal outline when viewed from above. The PO is larger than the other OO and is so placed as to prevent the RPO and LPO from meeting, and the knob-like protrusion in the mid-portion of the PO is more prominent than the ones on the other OO, particularly when the calyx is viewed in profile. In the genotype species, there is a slight offset between the PO and PB but the other OO are more nearly radial in position. In *L. obtusus* which is considered to be an immature specimen, there is an offset of about 3 degrees between all OO and BB.

Remarks.—The genus *Lampadosocrinus* is related to *Dichostreblocrinus* in its general appearance. It possesses an infrabasal circlet, 5 BB, 5 offset OO, and an anal notch at the upper edge of the BB between the PB and RPB. The infrabasal circlet of *Lampadosocrinus* possesses five plates while the number of plates in the infrabasal circlet of *Dichostreblocrinus* is unknown. The BB of *Lampadosocrinus* are distinctive in that each plate bears a prominent node at mid-position. This feature is present on Peck's holotype of *D. minutus*, but he fails to mention

it in his description, and his illustrations do not emphasize it. Also the longitudinal axes of the BB are not twisted in the characteristic fashion of Weller's genotype. The BB show no axial deformity. Another argument in favor of generic distinction is that the oral plates of *Lampadosocrinus* are not all uniformly displaced to the left from an interradial position as in *Dichostreblocrinus*. The PO and PB of *Lampadosocrinus* are just slightly offset, but the LPO, LAO, and RAO are almost radial in position. The offset of the RPO is less radial in position than the latter three OO, but is more nearly so than the PO. In immature specimens, the offset of the anterior OO is less pronounced, and their positions correspond to a more uniform arrangement in relation to the BB. The OO of *Lampadosocrinus* are also distinctive in the possession of marked, pointed, lateral extensions of their mid-sections. This feature is not as pronounced on the OO of *Dichostreblocrinus*.

The generic name is derived from the Greek noun *lampados*, torch.

Occurrence.—St. Joe formation, Oklahoma, Lake Valley formation, New Mexico, and Fern Glen formation, Missouri.

LAMPADOSOCRINUS MINUTUS (Peck)
Text-fig. 4—19–21

Dichostreblocrinus minutus PECK, 1936, Jour. Paleont., vol. 10, no. 4, p. 289, pl. 46, fig. 27–32.

The calyx is high and expands evenly to its greatest width at the upper margins of the oral circlet. The calyx of the figured specimen has a length of 0.66 mm., a width of 0.51 mm., and a H/W ratio of 1.3. The five IBB form a rather high erect basal circlet which forms about two-tenths of the total height. The five BB are longer than wide, and each is sharply protruded in midposition. They constitute about three-tenths of the calyx height. A small indistinct anal plate is present in a notch between the upper right shoulder of the PB and the upper left shoulder of RPB. The five large oral plates which constitute about half of the calyx height are the most dominant elements of the calyx structure. They are nearly radial in position except at the posterior where there is only a slight offset between the PO and PB. The interoral sutures are impressed in their lateral portions, but on the ventral surface they are marked by ridges. A knob-like protrusion is present in the midsection of each oral, and this augments the dominant appearance of the oral circlet. In this repect, the PO is especially pronounced, and the swelling continues into the ventral surface of the plate.

Remarks.—It appears that this species does not develop an observable anal opening until the specimens reach an approximate height of 0.6 mm. Peck's genotype which possesses a marked anal opening is about 1.0 mm. in height. Consequently, the first appearance of the anal might be considered as the first stage of maturity for this species.

Occurrence.—Thin shale partings between the thin limestone lentils at the base of the St. Joe formation below the high bluffs of crinoidal limestone overlooking the Illinois River, one-quarter mile south of "Eagle's Nest" fishing camp, northeast of Tahlequah, Oklahoma.

Types.—The figured homeotype was collected by the senior author and is to be deposited in the Springer Collection at the U. S. National Museum.

LAMPADOSOCRINUS OBTUSUS, n. sp.
Text-fig 4—16–18

The calyx of this species has the appearance of being short and squat although the H/W ratio of 1.3 shows it to be somewhat elongated. The holotype calyx is 0.51 mm. high by 0.39 mm. wide. The five IBB form a narrow erect circlet that is sharply defined from the adjacent basal circlet. The five BB are rather short, strongly tumid plates with fundamentally quadrate outlines. The sutures between the BB and the OO are sharply impressed, and the OO are uniformly offset about three degrees from the BB. The five OO are large, tumid elements with the ventral portions forming a mildly convex surface. The PO is larger and more pronounced than the other four. The entire surface of this form is finely pitted.

Remarks.—The OO of *L. obtusus* are slightly higher than those of *L. minutus*, and the BB are slightly shorter so that ratio of width to height is equalized between the two species. In *L. minutus* the protrusion of the BB is due to node-like structures, whereas in

L. obtusus the entire basal plate is tumid. As previously noted, the OO in *L. minutus* are nearly radial in position except for the PO and PB, but in *L. obtusus* all the OO are uniformly offset about 3 degrees.

Occurrence.—Nunn member, Lake Valley formation. Wash low in canyon to the north of Marble Canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Types.—The figured holotype was extracted from a shale sample collected by Dr. Carl C. Branson. It is to be deposited in the Springer Collection at the U. S. National Museum.

Unclassified

Genus PASSALOCRINUS Peck, 1936

PASSALOCRINUS TRIANGULARIS Peck, 1936

Text-fig. 4—22–27

This interesting species is abundantly represented in the Nunn member of the Lake Valley formation of New Mexico, the St. Joe formation of Oklahoma, and the pre-Welden shale of Oklahoma. All the specimens which we have observed from these three localities are remarkably similar to Peck's specimens from the Fern Glen formation of Missouri and are considered by us to be the same species.

Occurrence.—Nunn member, Lake Valley formation. Wash low in canyon to the north of Marble Canyon in the Sacramento Mountains, south of Alamogordo, New Mexico.

Thin shale partings between the thin limestone lentils at the base of the St. Joe formation, below the high bluffs of crinoidal limestone overlooking the Illinois River one-quarter mile south of "Eagle's Nest" fishing camp, northeast of Tahlequah, Oklahoma.

Shale bed immediately below the main ledge of the Welden limestone formation in a railroad cut south of Ada, Oklahoma: sec. 27, T. 3 N., R. 6 E.

Types.—The homeotypes were collected by Dr. Carl C. Branson and the senior author and are to be deposited in the Springer Collection at the U. S. National Museum.

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MANUSCRIPT RECEIVED APRIL 19, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1248–1257, 1 TEXT-FIG., SEPTEMBER 1956

THREE GENERAL PRINCIPLES FOR A SYSTEM OF CLASSIFICATION OF FOSSIL CONCHOSTRACANS

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ABSTRACT—Three principles are formulated and illustrated for use in the classification of fossil conchostracans: (1) *Exclusion*—this principle establishes the inadequacy of the available evidence for the assumption of a one-to-one relationship between fossil and modern conchostracans; (2) *Effectiveness*—this principle pertains to the limited utility of a single morphological character as a taxonomic device and recognizes that the final test of adequacy is in its actual use in discriminating between fossil carapaces; (3) *Total Morphological Pattern*—this principle indicates the conditions under which a single morphological character as a taxonomic device can have extended application.

INTRODUCTION

FROM the point of view of paleontology and geology, the fossil Conchostraca are the most important order of Branchiopoda found in the rock column. Numerous problems concerning this order came to the fore when a recent systematic review of the taxonomy of this group was prepared for the Treatise on Invertebrate Paleontology. Table 1 compares three distinct classificatory systems and in essence summarizes these problems. The purpose of this paper is to provide the background information, related material, and to elucidate the principles used by different workers in order to amplify Table 1.

The material is presented in a general form as the "Given" and the "Problem." It is thought that this manner of presentation will prove helpful to students of this as well as other fossil groups. The principles that are stated, defined, and illustrated constitute only a few which have been selected from among many possible ones. These are formulated as useful points of reference rather than as a sine qua non.

EXAMPLE 1

Given.—(a) Fossil material known predominantly from the carapace or particular characters of the carapace.

(b) Families of living forms classified on the basis of soft parts, yet bearing carapaces closely resembling those of fossil specimens.

(c) Rare occurrences of fossil material with both shell characteristics and soft parts preserved.

Problem.—Using (c), can (a) be placed in genera directly assignable to (b)? Exclusive of (c) can any given genus of (a) be placed in (b)?

Discussion.—The three instances of fossil conchostracans in which soft parts have been preserved are: *Limnestheria ardra* Wright (1920) (Text-fig. 1—1); *Lynceus* (=*Paleolynceus*) *stchukini* Chernyshev (1940); and *Estheria minuta Alb.* (=*Isaura bunteria*) Bill, 1913 (Text-fig. 1—6). Wright's specimens from the Kilkenny Coal Measures of Ireland had such soft parts as trunk limbs and telson excellently preserved while, in general, for carapace characteristics, the reverse was true. The new genus which Wright established and which was based on the soft parts of these specimens has never been disputed by any zoologist although reference to Table 1 will indicate that paleontologists are not quite in agreement on the familial assignment of this genus.

Chernyshev's specimens which were referred to the Lynceidae were so poorly preserved and figured, that independent verification is impossible from study of his meaningless photographs. The limited preservation of soft parts as described by that author permits no definite conclusion to be drawn as to assignment on a family level. However, the carapaces are reported to lack growth lines. This feature distinguishes the living Lynceidae and hence reference to Table 1 will show that all workers agree on placing it in that family.

If paleontologists admit that the only characteristic of the Lynceidae that they

can confirm in fossil material is the absence of growth lines, then it follows that *Limnestheria* Wright cannot belong to this group since its carapace bore growth lines (cf. Text-fig. 1—1 and 1—4).

Nevertheless, Kobayashi (1954) used soft part evidence in one instance and ignored it in another. Thus, he assigned Chernyshev's specimens as did Raymond (1946) earlier to the Lynceidae. This was done even though the fossilized impressions of the soft parts do not and cannot clearly prove that it belongs to this family of living conchostracans. Yet, for *Limnestheria*, Kobayashi utilized the characteristics of the soft parts (i.e., in both the living *Lynceus* and fossil *Limnestheria* only one pair of trunk limbs in males are modified as claspers—a feature that occurs in living *Cyclestheria* as well) and ignored carapace characters, i.e., the presence of growth lines. Therefore, if we allow Kobayashi's assignments to the Lynceidae to stand, the family recognized by zoologists as being "without growth lines" (Pennak, 1953, p. 344) will contain forms having growth lines (*Limnestheria*).

The third instance of soft part preservation was reported by Bill. He found a vaguely defined impression of an estherian-like animal (Text-fig. 1—6) and associated but not attached to it, shells identifiable as those of *Estheria* (=*Isaura*) minuta (Text-fig. 1—9). He then, with some doubts, assigned the soft part impression to the genus and species in which shells of the *minuta* type had previously been placed. Careful study of the inadequate published evidence failed to satisfy the writer that impression and shell were in fact one and the same species. Wright earlier expressed a similar opinion (1920, p. 189–190).

Still, we are confronted with the problem of assigning this material as well as that of the other examples. In making assignments one needs to pay attention to the almost unanimous disapproval of zoologists specializing in the taxonomy of living forms. Their opposition expresses itself against the assignment of fossil conchostracans directly to biologically defined families and genera.

Proposed solution.—We must sharply differentiate between taxonomic assignments of various kinds: (a) those made solely on the basis of soft parts, (b) soft parts plus shell characteristics, (c) shell characteristics only. If we choose one or the other of this triad, then consistency becomes most important. For example, if assignment is chosen on the basis of (c), then we cannot sometimes assign on this basis and sometimes on the basis of (b) or (a). Further, our choice must be made on some meaningful or verifiable criterion. In the case of classification of fossil conchostracan shells, a meaningful criterion would be one in which there is evidence of biological difference—such, for example, as whether a conchostracan's growth is not reflected by growth lines on the carapace (*Lynceus*) or whether it is reflected by growth lines peripherally added to the carapace.

Other than Chernyshev's specimens and living *Lynceus*, both having carapaces that lack growth lines, there is no certainty of identity. To acknowledge this uncertainty a subfamily, **Paleolynceiinae** n. subfam., is here established to include *Lynceus*-like fossil material.

Similarly, although Wright's material is in a remarkably fine state of preservation, many aspects of the soft part anatomy are not known: number of body segments, presence or absence of a haft organ, etc. Thus, we may conclude that although the material is biologically adequate for assignment on a generic basis, it is not so on the familial level. We also have clear evidence of soft parts directly attached to the carapace, and some carapaces of this type bear about ten growth lines surrounding a broad, smooth, umbonal area (Text-fig. 1—1). These carapace features are found in living *Limnadia* (Text-fig. 1—2) as well.

In addition to Wright's specimens, there are several *Limnadia*-like fossil genera; *Cornia*, *Estheriina*, *Paleolimnadopsis*, *Vertexia*. To accommodate these a subfamily is here established, **Paleolimnadiinae** n. subfam. Kobayashi (1954) subdivided the Limnadidae into two subfamilies which the present writer considers needlessly complex in the present state of knowledge and the new subfamily incorporates these two.

Assignment of Bill's material posed a more difficult problem. In view of the inconclusiveness of the published evidence and because it is not subject to independent verification, it was thought that the estherian

TABLE 1—FOSSIL CONCHOSTRACANS: COMPARISON OF THREE CLASSIFICATIONS*

Raymond, 1946	Kobayashi, 1954	Tasch, MS
Family: Cyzicidae		Family: Isauridae
Bairdestheria 1		*Isaura* s.s.
		Isaura (*Euestheria*) 6 (1, 8, 27)
		Isaura (*Lioestheria*) 2
Family: Lioestheriidae	Family: Lioestheriidae	
Lioestheria 2	Subfam.: Lioestheriinae	
Erisopsis 3	*Euestheria* 6 (1, 8)	
Asmussia 4	*Lioestheria* 2	
Orthothemos 5	*Pseudoleaia* 25	
Euestheria 6	Subfam.: Asmussiinae	Family: Asmussidae
Pseudestheria 7	*Asmussia* 4	*Asmussia* 4 (3, 5)
Palaestheria 8	*Quadriasmussia* 26	*Quadriasmussia* 26
Estheriella 9	*Estherites* 27 (5, 13)	*Rhabdostichus* 20 (13, 19)
Dadaydedeesia 10	Subfam.: Cyclestheriodiinae	*Echinestheria* 30
Monoleiolophus 11	*Cyclestheriodes* 19	
Family: Lynceidae	Family: Lynceidae	Family: Lynceidae
Lynceus 12	*Lynceus* 12	Subfam.: Paleolynceiinae
	Limnestheria 15	*Lynceus* 12
Family: Limnadidae	Family: Limnadidae	Family: Limnadidae
Paleolimnadia 13	Subfam.: Estheriinae	Subfam.: Paleolimnadiinae
Pemphicyclus 14	*Estheriina* 28	*Estheriina* 28
Limnestheria 15	*Cornia* 29 (14)	*Cornia* 29 (14)
Limnadopsis 16	*Echinestheria* 30	*Paleolimnadopsis* 17
Paleolimnadopsis 17	Subfam.: Vertexiinae	*Vertexia* 31
Anomolonema 18	*Vertexia* 31	*Limnestheria* 15
	Paleolimnadopsis 17 (16)	
Family: Cyclestheriidae		
Cyclestheroides 19		
Incertae Sedis: *Rhabdostichus* 20	Family: Rhabdostichiidae	
	Rhabdostichus 20	
Family: Leaiadidae	Family: Leaiadidae	Family: Leaiadidae
Leaia 21	*Eoleaia* 32 (7)	*Leaia* 21 (22, 32, 7)
Hemicycloleaia 22	*Leaia* 21 (22)	*Discoleaia* 33
Praeleaia 23	*Monoleiopholus* 11	*Paraleaia* 24
Paraleaia 24	*Discoleaia* 33	*Trileaia* 35
	Paraleaia 24	*Quadrileaia* 34
	Bileaia 40	*Bileaia* 40
	Quadrileaia 34	*Monoleaia* 41
	Trileaia 35	*Acantholeaia* 37
	Mesoleaia 36	*Praeleaia* 23 (35, 39)
	Acantholeaia 37	*Pseudoleaia* 25
	Family: Estheriellidae	Family: Estheriellidae
	Praeleaia 23	*Estheriella* 9 (36, 38)
	Nyasestheriella 42	*Anomolonema* 18
	Anomolonema 18	*Nyasestheriella* 42
	Congestheriella 38	*Monoleiopholus* 11
	Estheriella 9	
	Metaleaia 39	

* The first number after the generic name enables the reader to locate a given genus in any of the three systems. The numbers in parentheses refer to genera placed in synonymy. Thus, in column 1 *Euestheria* is given the number 6. In column 2 it bears the same number for identification. In addition, the numbers 1, 8 occur in parentheses. This is to be read as follows: genera numbered 1, and 8 in column 1 were placed under synonymy of *Euestheria*. In column 3, the numbers after genus number 6 show that Tasch placed genus 1, 8, and 27 under synonymy. Genera not named originally in column 1 received a number in column 2 which will again be shown either directly or under synonymy in column 3. (Columns 1, 2, and 3 refer to Raymond 1946, Kobayashi 1954, and Tasch MS.)

soft parts of his specimen were less meaningful taxonomically than his find of the well-known carapaces of *Estheria* (= *Isaura*) ***minuta***. Despite this decision, the species is here renamed *Isaura* (*Euestheria*) ***bunteria*** to distinguish the fact that soft parts have also been reported for this specimen. If at some future date Bill's speculation can be independently validated by new finds showing *I. minuta* shells and soft parts in immediate

association, then assignment of the species will have to be reconsidered.

Some brief comments are needed on the genus *Isaura* which, it will be noted, is the proposed replacement of *Estheria* and *Cyzicus*. In a separate paper the *Isaura-Cyzicus* controversy will be documented and the reasons indicated for the use of the name *Isaura*. Here discussion is limited to the question, Can any estherian-type fossil carapaces be directly placed under *Isaura* even though they agree closely in carapace characters?

The only available material to illuminate the problem is the dubious material of Bill. Thus, one is led to conclude that at best all fossil estherians may be said to have estherid-like carapaces. This fact should be established in a distinctive manner. Therefore, *Isaura* s.s. applies only to living forms while *Isaura* (*Eustheria*) and *Isaura* (*Lioestheria*)—two subgenera of *Isaura*—embrace all fossils having carapaces like *Estheria* (=*Isaura*).

Both Raymond and Kobayashi faced this problem. In the case of the living *Limnadopsis* (Spencer & Hall, 1896) (Text-fig. 1—3), Raymond (1946, p. 270) assigned directly to it two fossil species (*L. sibericensis; L.? chilensis*). He also erected a new genus *Paleolimnadopsis* for "Limnadiidae similar to the modern *Limnadopsis*," in carapace characters. (This illustrates the problem under discussion.) Kobayashi corrected this by placing Raymond's *Limnadopsis* fossils under *Paleolimnadopsis*. Tasch concurred in this procedure. However, neither Raymond nor Kobayashi were consistent throughout, as shown earlier, and an inconsistent taxonomy is an absurdity.

In answer to the original problem posed earlier, a conclusion can be given by formulating the first principle:

Principle 1: *Fossil conchostracans cannot be directly assigned to biologically established families and genera of living conchostracans.* Only the indirect approach, i.e., placement in subcategories, subfamilies, subgenera can meet the limitations arising from the incompleteness of fossil remains known to date and at the same time satisfy the apparent relationship of fossil carapaces to those of living forms.

Although Kobayashi (1954, p. 13) realized that "there is no criterion identifying a fossil carapace definitely with any of the recent genera," Principle 1 extends this statement to include Recent families as well as genera and covers fossilized conchostracan soft parts. Implicit also is the requirement for uniform application to all conchostracans presently known. This requirement was violated by Kobayashi when he concurred in the placing of *Lynceus* and reassigned *Limnestheria* directly to the living Lynceidae.

EXAMPLE 2

Given.—(a) The umbonal region of a conchostracan carapace represents the juvenile growth stage.

(b) The mode of attachment of body to carapace in conchostracans is by a ligament inserted in the interior upper region of the umbo as well as by a strong adductor muscle inserted on the interior surface of each valve (Sars, 1896, p. 86, pl. 14).

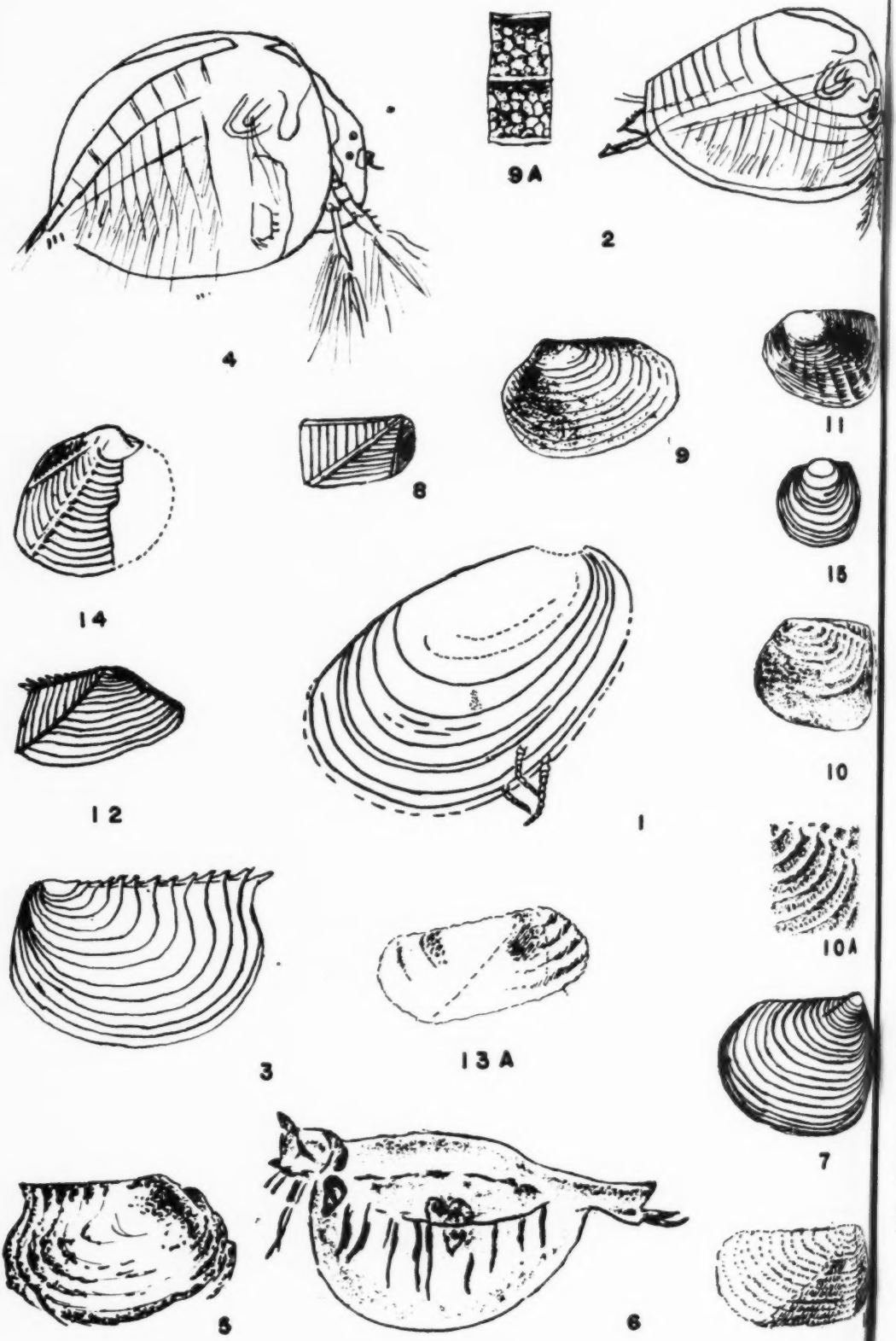
(c) The umbo is not fixed (e.g., subcentral or terminal) but can show an apparent shift in position relative to the growing carapace as a whole.

(d) Various fossil carapaces may show equivalent positions of the umbo yet differ markedly in general shape of the carapace, ornamentation, etc.

Problem.—Can we establish as a principle of classification that in all instances position of the umbo shall be regarded as more important in a taxonomic sense than any other feature of the carapace (cf. Kobayashi, 1954, p. 19) or can we establish selected instances when this seems indicated?

Discussion.—If the primacy of the position of the umbo in all instances is granted for the purpose of this discussion, then the classification systems of Table 1 should be based entirely on this criterion. In that event all genera with, for example, subcentral umbos (regardless of other differences) would be grouped together. Thus, *Bileaia* (Text-fig. 1—14), *Acantholeaia* (Text-fig. 1—12) to cite a few examples, would have to be taken out of the family Leaididae and placed in Kobayashi's subfamily Asmussinae, which contains only forms with subcentral umbos.

Such rigid application of the primacy of umbo position is avoided by Kobayashi, for he assigned carapaces, all of which have subcentral umbos, to different families. In fact,



TEXT-FIG. 1

in assigning the genera named above as well as other leaians, he noted that the "presence or absence of radial ribs in the umbonal area" is the essential criterion and ignored entirely umbonal position (1954, p. 35).

Although Kobayashi argued that "umbonal position must be a more important criterion than the sculpture" (1954, p. 29), this did not prevent him from excluding *Rhabdostichus* which has a subcentral umbo, from the Asmussinae (a family erected to embrace such forms) nor from placing equal or more stress on the fact that the test is "striated or reticulated" when he diagnosed this genus. Similarly, although *Cyclestheroides* (Text-fig. 1—15) has a subcentral or central umbonal area, shape of carapace, which is subcircular in this instance, is considered a more important criterion.

These illustrations emphasize the fact that the criterion of umbo position was employed selectively in Kobayashi's classification. In other words, sculpture and/or carapace shape gained ascendancy in the hierarchy of criteria on an arbitrary basis—not because of a "natural" classification (Kobayashi, 1954, p. 35) but rather because of the prominence of one carapace feature over another as interpreted by a particular author.

In Kobayashi's classification, *Estherites* (=*Isaura*), which was erected to replace the preoccupied *Estheria*, is also assigned to the subcentral umbo grouping under the Asmussinae. However, a great number of *Estheria*-like carapaces do not have subcentral umbos. In fact, surface sculpture for this group affords a sharper and more subtle discriminatory device. Other workers and the writer have been able to distinguish between two subgenera, (*Euestheria*) and (*Lioestheria*) of *Isaura* based on surface sculpture and without regard for umbo position or carapace shape.

As for Raymond's family Lioestheriidae, he readily acknowledged "it is with regret" (1946, p. 230) that he set up the family as a dumping ground for "most of the older fossil conchostracans." He stated that he had been "compelled to do so" when he realized that fossil conchostracans could not be assigned to the biologically based families Cyzicidae and Leptestheriidae which could not be separated on the basis of shell characters alone. In brief, he really tried desperately hard to fit fossil conchostracans into modern families and genera and the measure of his despair is expressed in the polyglot family, Lioestheriidae.

Kobayashi (see Table 1) subdivided the cumbersome Lioestheriidae into three subfamilies, Lioestheriinae (with terminal or subterminal umbos), Asmussinae (with subcentral umbos), and, as noted above, Cyclestheroidiinae (with subcircular carapace). His diagnosis of the family refers to its members as having "growth lines on the carapace; test smooth and ornamented with

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TEXT-FIG. *1*

(The source of each illustration is given after the magnification. Fig. 1—2 and 1—4 are intentionally diagrammatic.)

1—Limnestheria ardra Wright, ×7 (Wright, 1920, text-fig. 4).
2—Limnadia lenticularis (L.), a modern form, ×5 (Sars, 1896, pl. 14, fig. 1).
3—Limnadopsis tatei Spencer and Hall, a modern form, ×3 (Spencer & Hall, 1896, pl. 22, fig. **20).**
4—Lynceus brachyurus Müller, a modern form, ×11 (Sars, 1896, pl. 18).
5—Palaeolimnadopsis carpenteri Raymond, paratype, ×1½ (Raymond, 1946, pl. 4, fig. 7).
6—Isaura bunteria (Bill) Tasch, ×20 (Bill, 1913, pl. 15, fig. 3).
7—Cyzicus (=*Isaura* Joly) *cycladoides*, a modern form, female shell, ×3 (Daday, 1915, pl. 73, fig. b).
8—Leaia leidyi (Jones) ×3½ (Jones, 1862, pl. 5, fig. 11,12).
9-9a—Isaura minuta (Goldfuss) von Zeiten, 1833. *9*, ×5 (Jones, 1862, pl. 2, fig. 1), *9a*, detail, ×50 (Idem.)
10-10a—Monoleaia unicostata (Reed) Tasch, n. g. *10*, ×10 (Reed, 1929, pl., fig. 17), *10a*, detail, ×30 (Idem.)
11—Estheriella nodocostata (Giebel), ×6 (Jones, 1891, pl. 2, fig. 11).
12—Acantholeaia regoi Almeida, ×3 (Almeida, 1950, text-fig. 2-4).
13-13a—Pseudestheria leaiformis Raymond. *13*, holotype, ×6 (Raymond, 1946, p. 246, text-fig. 2), *13a*, sketch of holotype, ×6 (CGS 12398).
14—Bileaia curta (Reed) Kobayashi, ×7 (Reed, 1929, pl., fig. 18).
15—Cyclestheroides picardi (Kobayashi), ×7 (Picard, 1909, pl. 23, fig. 27).

Estherian-type sculpture" (1954, p. 131). Thus, although elsewhere (see above) he considers position of umbo more important than sculpture, in retaining Raymond's family this is effectively denied, because sculpture is considered to be a familial and position of the umbo a subfamilial character. The former thus is given wider and the latter a more restricted application.

Taking these and related factors into account, the writer is impelled to raise Kobayashi's subfamily, Asmussinae, to familial rank. Hence, a new family, **Asmussiidae**, is here established. The presence of a subcentral umbo that "rise(s) slightly above the generally straight but occasionally arcuate dorsal margin" (Tasch, MS) characterizes the new family. This carapace feature is thus accorded wider application than surface sculpture for selected genera which group more readily when the former criterion has primacy.

All genera with subcentral umbos are not indiscriminately dumped into this new family. Rather, it is applied selectively. Fossil estherians, for example, whether they do or do not have this morphologic feature, were segregated as noted earlier, on the basis of surface sculpture. Kobayashi's argument against this approach (1954, p. 13–17) would probably be that living families and genera cannot be discriminated when sole reliance is placed on surface sculpture. However, by Principle 1 we are not constrained to a mere one-to-one relationship between fossil and living conchostracan carapace morphology. All reference to modern forms is not thereby eliminated—a point which is acknowledged in "given" items (a) and (b) of Example 2.

These and similar considerations lead to the second principle for a classification of fossil conchostracans:

Principle 2: *Based on the available evidence, any given morphological character (such as umbonal position) cannot discriminate effectively among fossil carapaces in all instances.*[1]

In lieu of biological validation of our taxonomy, the sole appeal that can be made is to the criterion of *effectiveness*. It simply refers to the success achieved in discriminating between assemblages of fossil carapaces when one system is used rather than another. Any attempt at a "natural" classification in view of Principle 1 is premature, ill-advised, and often misleading. Hence, systems of classification for this group are merely progress reports arising from a given worker's interpretation of the evidence.

[1] A given morphological character can have extended application in selected cases. See Example 3, and Principle 3.

EXAMPLE 3

Given.—(a) Umbo represents juvenile stage [same as Example 2, (a)].

(b) Carapace characters are defined as follows:

(.1) *Costae:* closely spaced radial ridges, grading from fine to coarse, that become obsolete near the umbo and do not cross it. Generally more than five on any valve.

(.2) *Ribs:* strongly expressed radial ridges with interval of variable width between any two, that radiate from and cross umbo. Never more than five on any valve.

(c) That both (b.1) and (b.2) served the same apparent function, namely, to strengthen the carapace; that although (b.2) had fewer radial ridges, their stronger expression and disposition on the carapace could accommodate as much stress as (b.1).

Problem.—Despite (c) and in light of (a), can we effectively (Principle 2) discriminate among fossil carapaces between (b.1) type and (b.2) type?

Discussion.—Reference to Table 1 will indicate that the genus *Estheriella* Weiss, 1876 (Text-fig. 1—11) which has a carapace with from five to seven costae (b.1) was distinguished from *Leaia* (Text-fig. 1—8) which has up to five ribs (b.2) by Raymond. Nevertheless, only in the case of *Leaia* where the presence of ribs was denoted as a familial character did he partially discriminate between these two genera. *Estheriella* was dumped in the Lioestheriellidae.

Kobayashi made a major contribution to the taxonomy of fossil conchostracans by refining Raymond's definition of the Leaididae to incorporate both the maximum number of ribs (five in number) and their relationship to the umbo (b.2) by reassigning many of Mitchell's (1925) estherians to the Leaididae, and, more important from the point of view of effectiveness, by raising the characteristics of *Estheriella*-type carapaces (b.1) from generic to familial rank, in a new family, Estheriellidae. He reasoned

(1954, p. 35) that because of (a) (See Example 3, "Given")

> the umbonal area must be a more important criterion than number and nature of the radials and their disposition. On the basis of this criterion, the Estheriellidae with smooth umbones and the Leaididae with these marked by radials are primarily distinguished.

There can be little doubt that this aspect of Kobayashi's classification represents a distinct advance over Raymond's. However, when the genera respectively assigned to either the Estheriellidae or the Leaididae are examined, many discrepancies are found to exist between Kobayashi's criterion cited above and more rigorously formulated in (b.1) and (b.2) and his application of it (cf. columns 1 and 2, Table 1, for these families).

Praeleaia Lutkevich, for example, has four or five radials that fan out from the umbo and thus, according to the above criterion, belong in the Leaididae. Kobayashi, nevertheless, placed it under the Estheriellidae. Tasch restored it to the former family as required by (b.2) and found that two of Kobayashi's genera, *Trileaia* and *Metaleaia* are synonyms of *Praeleaia* (see column 2, Table 1).

Study of the type material of *Monoleiopholus* Raymond showed that it possessed a single nodose costa that fades out anteriorly and does not reach the umbonal beak. Even though there is only a single radial, number of radials, as mentioned earlier, were thought to be less important than relationship of radial to umbo. Criteria must be consistently applied to retain meaning. Hence, this genus is placed under the Estheriellidae.

It also becomes clear that *Mesoleaia* Kobayashi, the holotype of which is *Posidonia nodocostata* Giebel, was erected on a misconception. Giebel (1857, p. 308, pl. 2, fig. 6) did not report five costa as Kobayashi thought, but seven ("Von ihm strahlen sieben Rippen" p. 309), and these fade out towards the umbo. Our accepted criterion requires its assignment to the Estheriellidae. In fact, it is a synonym of *Estheriella*.

A similar resolution was reached for the problem presented by *Congestheriella* Kobayashi. The type of this genus, *Estheriella lualabensis* Leriche (1913, pl. 1,2), has radial ridges that fade out on the umbo and do not traverse it. The number of these ridges "est rarement inférieur à cinq" (1913, p. 3). That is, they are usually greater than five. This would exclude it from the (b.2) type. Leriche distinguished his species from *Estheriella nodocostata* Giebel on the basis of carapace shape and ornamentation. These characters appear to the writer to have specific but not generic value. Leriche himself had also reached this conclusion. Kobayashi, however, gave them generic rank. Accordingly, Leriche's species is restored to the *Estheriella* and *Congestheriella* is regarded as a synonym of that genus.

There are but two additional genera to account for *Eoleaia* Kobayashi and *Monoleaia* Tasch. Kobayashi reassigned Raymond's *Pseudestheria leaiformis* (Text-fig. 1—13) from the Chevrie formation (Mississippian) of Nova Scotia. Raymond reported that the species had a "median depression as in *Leaia* but no distinct carinae" (=ribs) (1946, p. 246–247, text-fig. 2). Kobayashi reported the presence of "two radial ribs." Examination of the types (CGS 12398) revealed that (a) there is a depression on the carapace confined to the anterio-medial area (=medial depression of Raymond. Cf. Text-fig. 1—13, and my sketch of the type) but it can be interpreted as due to erosion rather than genetics, (b) that the elevated sides of the depression which fade out about the central region of the carapace are not distinct carinae as Raymond noted but are carinae only by inference, i.e., pseudocarinae. There is nothing on the type carapaces to indicate that these "carinae" are feebly expressed and hence represent "the most primitive" of leaians (cf. Kobayashi, 1954, p. 140). In fact, it is far from conclusive that they are leaians at all. Only the subterminal umbo and straight dorsal margin are suggestive that they might be leaians.

Based on these observations, *Eoleaia* is regarded as an invalid genus and, until it becomes clear where *Pseudestheria* properly belongs, it is placed under the synonomy of *Leaia*. Kobayashi's attributing phylogenetic significance to the apparent weakly expressed radial ridges, whose very existence is dubious, obviously goes far beyond the reasonable limits imposed by the available data (1954, p. 120).

Another instance where the accepted cri-

terion [Example 3, (b.1), (b.2)] was disregarded occurs in the assignment of Raymond's genus *Monoleiopholus* to the Leaididae. In this genus, which Tasch reassigned as described earlier, Kobayashi grouped *Leaia monocarinata* Lutkevich, *Leaia unicostata* Reed, and one of Mitchell's apparently monocarinate *Leaia* sp. undet.

Lutkevich (1941, p. 38, pl. 3, fig. 15–18) plainly stated that in *Leaia monocarinata* "one nodose keel" (=rib) proceeded from the beak and "towards the rounded posteroinferior angle." His photographs bear out this description. Similarly Reed (1929, pl. 17,17a) figured and described *Leaia unicostata* with a single rib extending from the umbo. To accommodate the species of Lutkevich and that of Reed, a new genus, *Monoleaia*, is here proposed.[2]

The above illustrations lead to a third principle of classification for fossil conchostracans. Before stating this principle, a brief definition of the concept of the "total morphological pattern" is required. This concept productively employed in the study of fossil and living vertebrates (Le Gros Clark, 1955, p. 15–17) can be shown to have applications to invertebrates as well. Further, it can have application even when, instead of several morphological characters taken as a complex, only a single one (carapace ribbing) is used. Thus, even a single morphological character is graduated into a character-complex when we extend it by definition. Although we may start with an individual character, like carapace ribbing, we can define *kinds* of ribbing (costa and rib), the *relationship* to umbonal area (i.e., whether radial ridges do or do not cross the umbo) and *number* (i.e., never more than five ribs or rarely fewer than five, most frequently many more than five, costae). In effect, then, observation of *kinds*, *relationship*, and *number* compound a single character into something much more—the nearest equivalent being "total morphological pattern."

Principle 3: *A single morphological character expanded by definition until it is the close equivalent of the total morphological pattern of the carapace does permit effective discrimination on the familial and generic level.*

For conchostracans, the application of Principle 3 allows ready discrimination of the Estheriellidae from the Leaididae.

[2] Family: Leaididae Raymond 1946 (emend. Kobayashi., 1954; Tasch, MS). Genus: *Monoleaia* (Tasch, MS, text-fig. 1–10) (=*Monoleiopholus* Raymond, 1946; emend. Kobayashi, 1954, *pro parte*). Type: *Leaia unicostata* Reed. Carapace subovate; imbricate or nodose radial extends from umbo to rounded posterior ventral margin. Included under this genus are: *Leaia monocarinata* Lutkevich. Excluded from this genus are: *Monoleiopholus conemaughensis* Kobayashi which is an estheriellid and *Leaia* sp. undet. Mitchell (1925, pl. 42, fig. 13) based on incompleteness of the available material.

ACKNOWLEDGEMENTS

This paper was made possible in part by research carried on under a Sigma Xi Grant-in-Aid during the summer of 1955. Illustrations were financed by a 1955 University of Wichita Research Fund Award. Both awards were made to facilitate preparation of the Branchiopoda chapter for the *Treatise on Invertebrate Paleontology*.

The writer is indebted to the Harvard Museum of Comparative Zoology for the opportunity to study Raymond's types and other conchostracan material on deposit there and for the laboratory facilities kindly made available. He is also indebted to the Canadian Geological Survey for loan of Raymond's types of *Pseudestheria leaiformis*.

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MANUSCRIPT RECEIVED FEBRUARY 22, 1956

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 5, P. 1258–1274, 7 TEXT-FIG., SEPTEMBER 1956

PALEONTOLOGICAL NOTES

AN IMPROVED METHOD FOR SEPARATING FOSSIL SPORES AND POLLEN FROM SILICEOUS ROCKS

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ABSTRACT—A method is described in detail for separating fossil spores and pollen from siliceous rocks. Slightly soluble calcium fluoride is prevented from forming by removing the carbonates with hydrochloric acid. Organic materials are removed with Schulze's solution followed by a sodium hydroxide solution, and mineral residues are removed with a heavy liquid.

Fossil spores and pollen are found in a variety of sedimentary materials that are not highly metamorphosed. More or less satisfactory methods for separating the tiny microfossils from the various matrices including carbonate and siliceous rocks, salt, anhydrites, peats and coals are reviewed by Sittler (1955). However, siliceous rocks are of particular interest to the stratigraphic palynologist. These rocks are abundant in many sedimentary sections, and the dark-colored finer grained ones may contain numerous microfossils. Therefore, more satisfactory methods are being sought for separating fossil spores and pollen from siliceous rocks.

The hydrofluoric acid method described originally by Assarsson & Granlund (1924) has been modified to produce samples with less debris mixed with the microfossils. Reissinger (1950) treated the crushed rock with cold 6 per cent hydrochloric acid for 24 hours followed by hot acid of the same concentration for 2 hours. The hydrochloric acid dissolves carbonates. Calcium carbonate will form very slightly soluble calcium fluoride if it is not removed before the hydrofluoric acid is added.

Norem (1953) used a heavy liquid with a specific gravity of 2.0 to remove insoluble minerals.

In addition to these modifications, Kuyl, Muller & Waterbolk (1955) used Schulze's solution to oxidize organic materials in the residues from the hydrofluoric acid treatment, and the oxidized materials were dissolved in a potassium hydroxide solution.

Plant microfossils separated from siliceous rocks by the modified hydrofluoric acid method of Assarsson & Granlund are relatively free of debris. Minerals are removed completely, and organic materials that remain in the sample are mostly plant or animal tissue fragments and particles with a chemical composition similar to that of the microfossils. The following is a step by step procedure for the separation of fossil spores and pollen from these rock types.

SEPARATION PROCEDURE

1. Select sample representative of stratigraphic interval to be examined.

2. Wash sample with distilled water to remove surface contamination.

3. Crush (do not grind) until sample will pass through 20-mesh sieve.

4. Mix crushed material to eliminate stratification and weigh approximately 20 gm. sample into 250 ml. plastic (polyethylene) or copper beaker.

5. Test sample for presence of carbonates by adding a few drops of dilute (1:5) hydrochloric acid. If no carbonates are present, proceed to step 6. If sample effervesces strongly, add HCl very slowly until sample is covered. When effervescence ceases, fill beaker with distilled water, stir sample and allow residue to settle. Repeat washing twice. After final washing, drain off water very carefully.

6. Add technical grade hydrofluoric acid slowly until beaker is $\frac{1}{4}$ to $\frac{1}{3}$ full and digest for 12 to 16 hours. Stir occasionally with a plastic rod. (Hydrofluoric acid is very corrosive to glass and metals. Use under an efficient fume hood only. Hydrofluoric acid burns are painful and difficult to heal. Operator should wear protective apron, gloves, and face shield.)

7. If sample is not broken down com-

pletely, decant spent acid and add fresh. Continue digestion until disintegration is complete. (Decomposition of some samples can be speeded up by boiling the hydrofluoric acid for a few minutes in a copper or monel beaker.)

8. Allow residue to settle, decant supernatant liquid and add distilled water. Stir sample, settle and decant liquid. Repeat washing. This washing in the original vessel eliminates the necessity for handling concentrated acid in the next step.

9. Transfer residue to 50 ml. glass centrifuge tube and quickly add distilled water, stir, centrifuge and decant. Repeat washing. (Centrifuge tubes will become frosted eventually from exposure to the dilute acid. However, the life of the tube can be prolonged by washing the acid out of the residues without unnecessary delay.)

10. Add about 25 ml. freshly prepared Schulze's solution (1 part saturated potassium chlorate solution and 2 parts concentrated nitric acid). Digest in a fume hood with occasional stirring for 12 to 16 hours.

11. Pour off supernatant liquid and wash residue by adding distilled water, centrifuging, and decanting. Repeat washing twice.

12. Add about 25 ml. 10 per cent sodium hydroxide and stir. When black color turns to brown (about 20 minutes) fill tube with distilled water and centrifuge. Repeat washing until water stays clear. Wash residue through a 60-mesh sieve and discard coarse particles. If mixture does not turn brown when the alkali solution has been added, repeat treatment with Schulze's solution.

13. Wash residue three times with 95 per cent alcohol. If no light-colored mineral sediment is observed, transfer to small vial with alcohol, add 3 drops of 0.1 per cent safranin-o in alcohol, and prepare slides. (See section on preparation of permanent slides.)

14. If light-colored mineral sediment is observed in bottom of tube in step 13, fill tube with 2.0 sp. gr. alcohol-bromoform mixture. Stir mixture vigorously so that slurry is thin and well mixed. The organic particles, including spores and pollen, can then rise easily to the top.

15. Settle the heavy solids by centrifuging. Transfer the heavy liquid with the floating organic materials to a small separatory funnel. Wash any organic material clinging to the sides of the tube into the funnel with a fine stream of heavy liquid from a wash bottle. Let the mixture stand in the separatory funnel for several minutes to permit the organic particles to rise to the top again, and then draw off the minerals and most of the heavy liquid from the bottom of the funnel.

16. Flush the organic residues and remaining heavy liquid into a glass centrifuge tube with 95 per cent alcohol. Centrifuge sample and decant. Repeat washing with alcohol until the liquid remains clear when poured into a beaker of water. Alcohol containing bromoform will turn white when poured into water.

17. Transfer to vials, stain, and prepare slides as follows.

PREPARATION OF PERMANENT SLIDES

1. Clean slides and cover slips thoroughly. Coat area of slide receiving spore-material with a thin suspension of egg albumin and dry with gentle heat (45°C. maximum). The albumin sticks the spores to the slide preventing the latter from being floated away by the diaphane.

2. With medicine dropper, place a drop of well-mixed residue from the sample preparation procedure on warm micro-slide and spread over area about equal in size to the cover slip. Allow alcohol to evaporate.

3. Add one drop of diaphane and lower cover slip onto diaphane. After diaphane has spread to, or nearly to, edges of cover slip, press the latter down gently with handle of dissecting needle to squeeze out excess diaphane and make a thin mount.

4. Label and place slide on warming table for two or three days.

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MANUSCRIPT RECEIVED MAY 7, 1956

NONMARINE MOLLUSCA FROM THE NORTH PARK FORMATION OF SARATOGA VALLEY, WYOMING

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ABSTRACT—Three new species of gastropods, *Stagnicola saratogensis*, *Anguispira holroydensis*, and *Vertigo praecoquis*, are described from the Upper Miocene portion of the North Park formation of southeastern Wyoming. Also described are specimens of *Menetus? nebrascensis* (Evans & Shumard), previously known from the upper part of the White River series of South Dakota.

INTRODUCTION

A small collection of fossil mollusks, mostly gastropods, was submitted to me for identification by Mr. John de la Montagne of the Department of Geology, Colorado School of Mines. These fossils were collected from the North Park formation of Saratoga Valley and vicinity, southeastern Carbon County, Wyoming. After some study it was apparent that the collection included new species and species in need of further definition. Description of these is the purpose of the present paper. Formal designation of them will not only be of assistance to Mr. de la Montagne in his account of the stratigraphy of the North Park formation, but may also be helpful to others who find similar material in Tertiary deposits of adjacent areas. Far too little is known about the continental molluscan faunas of North America during middle and late Tertiary time. For the privilege of studying these specimens I wish to thank Mr. de la Montagne. With his permission the holotypes of new species are being deposited in the invertebrate paleontology collection of the United States National Museum.

The age of the North Park formation in the Saratoga area is known from mammalian fossils to range from middle to late Miocene, and possibly as young as early Pliocene, although this has not yet been proved. From the data supplied by Mr. de la Montagne it is evident that the specimens here described are from the late Miocene (Barstovian) part of the sequence. The stratigraphic position of these occurrences will be more fully described in a forthcoming report by Mr. de la Montagne.

DESCRIPTIONS

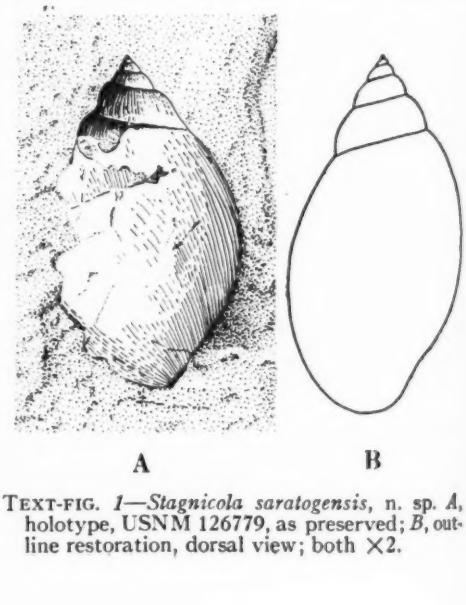
Class GASTROPODA

Family LYMNAEIDAE

STAGNICOLA SARATOGENSIS, n. sp.

Text-fig. 1

Holotype.—USNM 126779; specimen consists of body whorl, with spire represented



A B

TEXT-FIG. 1—*Stagnicola saratogensis*, n. sp. *A*, holotype, USNM 126779, as preserved; *B*, outline restoration, dorsal view; both ×2.

by ventral side of whorls, seen from the interior, the whole on a piece of tuffaceous shale.

Occurrence.—SE ¼ sec. 17, T. 16 N., R. 83 W. Carbon County, Wyoming; from the dissected side of a terrace on the North Platte River. North Park formation, from the Upper Miocene (Barstovian) portion.

Description.—Shell medium-sized to rather large for the genus, relatively broad; volutions four to five. Spire tapering regularly, acutely pointed, making up about one-third of the total length of shell. Body whorl well rounded but not inflated. Aperture unknown. Surface marked by fine, rather regular growth lines. Length of holotype (a large specimen), as preserved, 23.0 mm.; width, 12.4 mm.

Remarks.—One of the few fossil lymnaeids from the Tertiary of western North America that is comparable with the present one is *Stagnicola meekiana* (Evans & Shumard) (see Meek, 1876, p. 598), from the White River Oligocene of South Dakota. The resemblance is not particularly close, for the shell of *S. meekiana* is more slender, with a relatively long, tapering spire. Another broad-shelled lymnaeid, *Stagnicola scudderi* (Cockerell, 1906, p. 461), is known from the Florissant beds, but the shell is much smaller than that of the present species, and the apex of the spire is obtuse. Among living species there is some resemblance to the shorter forms of *Stagnicola catascopium* (Say). The shell of *S. saratogensis* may be described as appearing superficially like a reversed shell of *Physa gyrina*.

Family PLANORBIDAE

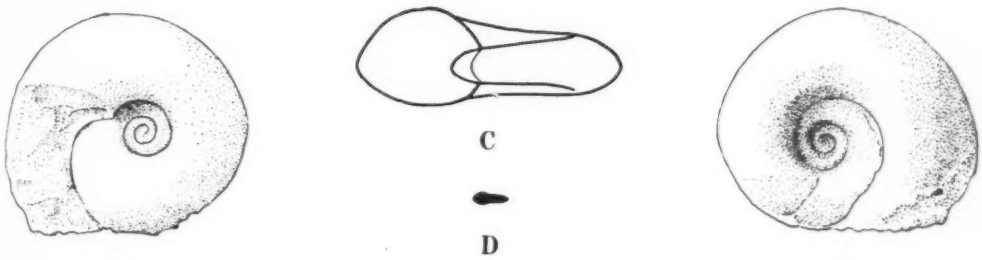
MENETUS? NEBRASCENSIS (Evans & Shumard)

Text-fig. 2

Planorbis nebrascensis EVANS & SHUMARD, 1854, p. 164.

Planorbis (*Menetus?*) *nebrascensis* MEEK, 1876, p. 600, 601, pl. 32, fig. 2a, 2b.

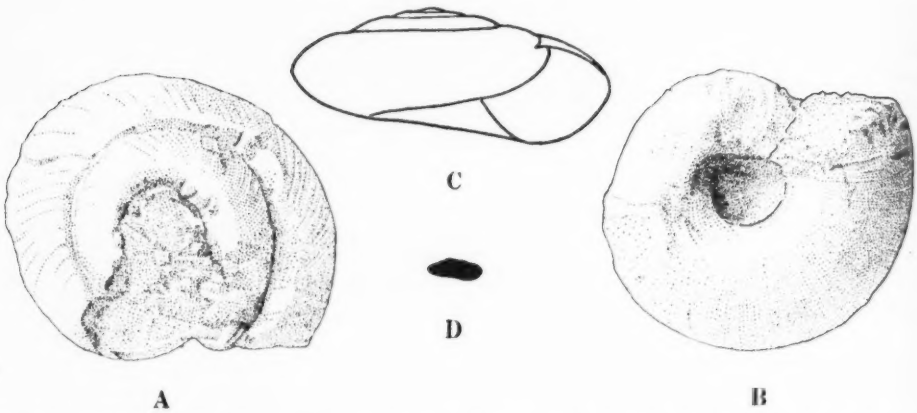
Occurrence.—The type specimens are from the White River series, headwaters of "Pinot's Creek," Grindstone Hills, South Dakota. The specimens here described are from the center of sec. 27, T. 15 N., R. 84 W., Carbon County, Wyoming; North Park formation, Upper Miocene portion.



TEXT-FIG. 2—*Menetus? nebrascensis* (Evans & Shumard), from North Park formation. *A*, left or apical view, ×7.5; *B*, right or basal view, ×7.5; *C*, outline restoration in ventral view, ×7.5; *D*, silhouette, ×1.

Description.—Shell small, biconcave, volutions about three and a half, rapidly expanding, each whorl partly but not completely overlapping previous whorl, so that parts of all whorls are visible on both sides. Spire and base impressed, the basal concavity being wider than that of the spire. Body whorl subangular at periphery. Maximum diameter of largest specimen from Saratoga Valley, 4.4 mm.; maximum breadth between apical and basal sides, 1.8 mm.

Remarks.—The above description is based on specimens from Saratoga Valley. Comparison with the descriptions given by Evans and Shumard and by Meek show close agreement on all features, including size. Meek's opinion that the species might represent the "subgenus" *Menetus* is tentatively followed here. It is supported by the small size and the subangular periphery. However, a characteristic feature of *Menetus* is the flat, rather than impressed, base. Among planor-



TEXT-FIG. 3—*Anguispira holroydensis*, n. sp. *A*, holotype, USNM 126780, as preserved, apical view, ×6; *B*, basal view of same, ×6; *C*, outline restoration in ventral view, ×6; *D*, silhouette, ×1.

bids a biconcave shell is most characteristic of the genus *Helisoma*, but in this the shells are relatively large, with well-rounded or multicarinate whorls.

Family ENDODONTIDAE

ANGUISPIRA HOLROYDENSIS, n. sp.

Text-fig. 3

Holotype.—USNM 126780; a nearly complete shell, somewhat damaged on the apical side.

Occurrence.—Holroyd Park, in the SE ¼ sec. 8, T. 12 N., R. 81 W., Carbon County, Wyoming. North Park formation; the stratigraphic position within the formation is not known, as the occurrence is isolated from the main sedimentary body. From stratigraphically equivalent beds about a mile northwest, Upper Miocene mammalian fossils have been collected.

Description.—Shell small; volutions about four; spire low; body whorl subangular at periphery. Umbilicus deep, its diameter about one-third that of shell. Surface of first one and a half whorls smooth, remainder with many fine retractive costulae, more distinct on apical than on basal surface. Maximum diameter of holotype 7.9 mm.; height as preserved, 3.3 mm.

Remarks.—The apical surface of the holotype is not completely preserved, but details of the inner whorls can be seen on other specimens, including a good natural impression of the surface. The ornamentation of the inner whorls, together with the general form of the shell, indicate a member of the Endodontidae. Such a small size suggests the genus *Discus*, but the low spire and subangular periphery are not typical of this genus. All of the shell characters except size point to the genus *Anguispira*. Shells very similar to the present ones in appearance are found in the living *Anguispira alternata* (Say) and *A. cumberlandiana* (Lea).

Family PUPILLIDAE

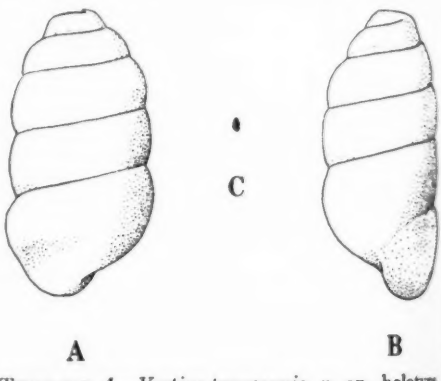
VERTIGO PRAECOQUIS, n. sp.

Text-fig. 4

Holotype.—USNM 126781; a complete shell.

Occurrence.—Same as *Anguispira holroydensis*.

Description.—Shell very small, ovoid-cylindrical, with rounded apex; volutions a little over four, convex; body whorl with



TEXT-FIG. 4—*Vertigo praecoquis*, n. sp., holotype USNM 126781. *A*, dorsal view, ×20; *B*, ventral view, ×20; *C*, silhouette, ×1.

shallow sinus on lateral surface near aperture. Surface apparently smooth. Aperture subcircular, with thickened rim, which is slightly indented by external sinus; probably dentigerous but details not known. Length of holotype, 1.8 mm.; maximum diameter, 0.9 mm.

Remarks.—This tiny shell is surprisingly modern in appearance. The subcylindrical shape suggests examples of the widespread *Vertigo gouldi* (Binney) of the Recent fauna, but in that species there are strong costulae. Smooth or slightly striate shells occur in *V. ovata* Say and *V. modesta* (Say). Modern species are differentiated by the variations in the complex dentition of the aperture. In the type specimens of *Vertigo praecoquis* the nature of the matrix and the very small size prevented these structures from being exposed by manual preparation.

The genus *Vertigo* is almost certainly represented by *"Pupa" arenula* and *"P" atavuncula* of White (1883, p. 46) from the Middle Eocene of Wyoming. This has been pointed out by Yen (1946, p. 499, 500). Unfortunately, the apertures of these species are also imperfectly known. The shell in both species is larger and more rotund than in *Vertigo praecoquis.*

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MANUSCRIPT RECEIVED APRIL 4, 1956.

MICROTUS PENNSYLVANICUS (ORD) FROM THE HAY SPRINGS LOCAL FAUNA OF NEBRASKA

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ABSTRACT—*Microtus pennsylvanicus* (Ord), the meadow vole, a member of the present fauna of Nebraska, is known from fossil remains in the American Museum of Natural History, which were taken with the Hay Springs local fauna of Sheridan County, Nebraska. On the basis of known Pleistocene faunas, the Hay Springs mammals are post-Pearlette ash in age. The fauna appears to be equivalent to those that lived during the late Illinoian and Sangamon.

The occurrence of *Microtus* in the Hay Springs local fauna of Nebraska has long been known (Matthew, 1918, p. 227; Hay, 1924, p. 305; Osborn, 1942, p. 1010). In the spring of 1944 while studying the holotypes of *Ondatra nebracensis* (Hollister) and *Capromeryx furcifer* Matthew, I examined a lower jaw of *Microtus* from the Hay Springs fauna which led to my statement (Colbert, et al., 1948, p. 625) regarding the occurrence of this vole in that fauna. Through the courtesy of Dr. G. G. Simpson I have been given permission to study and figure these specimens.

In the American Museum of Natural History collection there are parts of three lower jaws and two left upper incisors from the Hay Springs, Nebraska locality, collected by the American Museum Expedition of 1897.

Specimen AMNH 2711 is part of a left lower jaw with the incisor, M_1 and M_2. M_1 consists of a posterior loop, six alternating triangles and an anterior loop. The sixth alternating triangle opens into the anterior loop (Text-fig. 1B). M_2 consists of a posterior loop and four closed alternating triangles. Enamel is lacking on the anterior face of

M_1, the labial and lingual sides of the posterior loop of M_1 and the anterior face of M_2. The posterior loop of M_2 has an interrupted enamel pattern. A narrow dentine tract on the labial and lingual sides of the loop extends from the occlusal surface to the base of the tooth. The anteroposterior length of the occlusal surface of M_1 and M_2 is 5.3 mm.

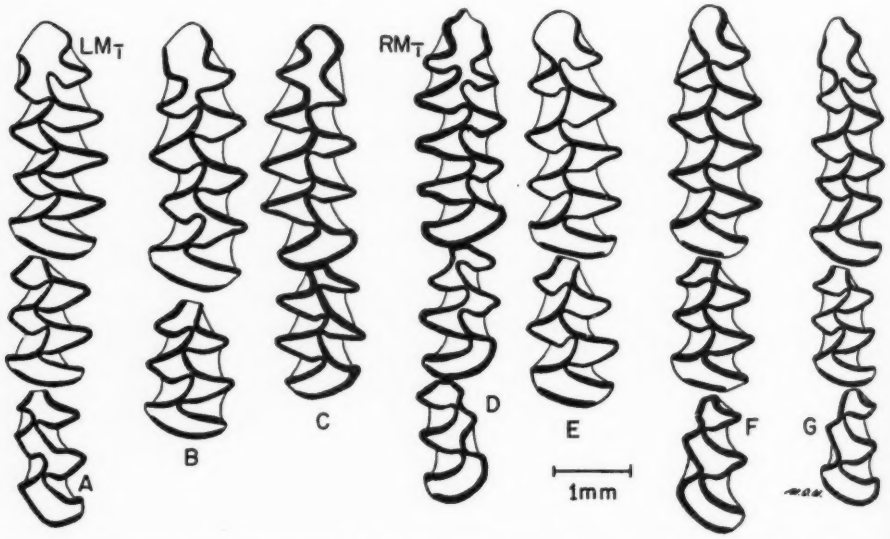
A fragmentary right lower jaw, AMNH 2712, contains part of the incisor, M_1 and M_2. The occlusal dental pattern is similar to that of the previous specimen, except that the sixth alternating triangle opens more widely into the anterior loop (Text-fig. 1C). The anteroposterior occlusal length of M_1–M_2 is 5.0 mm.

Specimen AMNH 2713 is a right lower jaw with an incisor and M_1–M_3. The occlusal pattern is like that of the other two specimens. M_3 consists of a posterior loop with the first and second alternating triangles broadly confluent. The third is closed off from the fourth triangle (Text-fig. 1D). The anteroposterior occlusal length of M_1 and M_2 is 4.75 mm.; that of M_1–M_3 is 6.5 mm. Dentine occurs in the reentrant angles of the teeth and is as well developed as in recent specimens. A deep pit occurs between M_3 and the ascending ramus as in Recent specimens of *Microtus pennsylvanicus*. The general shape of the lower jaw is like that of other fossil and Recent specimens of this species.

The two left upper incisors, AMNH 2714, are the size and shape of those of the Recent species.

The original American Museum label carries the name *Arvicola ?agrestis* but on the back of the label is written, "A note from O. P. Hay says: Not *A. agrestis*—an European species. Probably *Microtus pennsylvanicus*. O. P. H." At what time O. P. Hay made this identification is unknown but it must have been after the publication of his 1924 paper.

The number of closed alternating triangles of M_1 vary (5 to 6) in both Recent and fossil specimens. Text-fig. 1E is an occlusal view from a specimen, Univ. Michigan 31773, taken with the Berends local fauna of Oklahoma. Text-fig. 1F is an occlusal view of a specimen, Univ. Michigan 29333, from the Jinglebob local fauna. Both of these specimens have an M_1 with six closed alternating



TEXT-FIG. 1—*Microtus pennsylvanicus* (Ord), occlusal views of lower dentitions. All ×10. Drawings by Michael O. Woodburne. *A*, UMMZ 30048, left M_1–M_3, Recent specimen. *B*, AMNH 2711, left M_1 and M_2, Hay Springs local fauna. *C*, AMNH 2712, right M_1 and M_2, Hay Springs local fauna. *D*, AMNH 2713, right M_1–M_3, Hay Springs local fauna. *E*, UMMP 31773, left M_1–M_3, Berends local fauna. *F*, UMMP 29333, left M_1–M_3, Jinglebob local fauna. *G*, UMMZ 30013, left M_1–M_3, Recent specimen.

triangles posterior to the anterior loop. The two Text-figs. 1A and 1G of Recent specimens in the Museum of Zoology, University of Michigan, are given for comparison with the fossil occlusal patterns.

Age of the Hay Springs local fauna.—A stratigraphic control is lacking on this fauna since it appears that the exact location of the quarry or quarries is unknown. Matthew (1902, p. 317) gives the location as a bone-bed near the Niobrara River, not far from Hay Springs.

O. P. Hay (1924, p. 304) makes the following statement regarding the location:

> Many species of fossil vertebrates have been taken on Niobrara River, near a place now known as Old Grayson, not far from the present town of Grayson, from excavations known in the literature as the "Hay Springs quarry." The locality is said to be along a ravine about a mile away from the Niobrara River, and south of it.

Schultz & Stout (1948, p. 564) make the following remark regarding this early local ity:

> The American Museum of Natural History expeditions of 1893, 1897, and 1916 conducted minor quarry operations south of Hay Springs, but the exact locations of these quarries cannot now be determined.

A succession of Pleistocene faunas, for which there is a stratigraphic control, is known from Meade County, Kansas and Beaver County, Oklahoma (Hibbard, 1956, p. 146, fig. 1).

The earliest remains of *Microtus* in the Plains region are known from the Crooked Creek formation (Hibbard, 1949). This formation is tentatively considered as having been deposited during Kansan and Yarmouth time. The basal part of this formation consists of sand and gravel (Stump Arroyo member) which rests unconformably upon the Meade formation. The following fossils have been taken from the Stump Arroyo member (Hibbard, 1951) in Clark and Meade counties: *Megalonyx* sp., *Stegomastodon* sp., *Stegomastodon mirificus* (Leidy), *Nannippus phlegon* Hay and *Plesippus* cf. *P. simplicidens* (Cope). So far *Equus* s.s. and *Mammuthus* have never been taken from this sand and gravel. They are known from later deposits of this region (Hibbard, 1953). Above this sand and gravel member occurs sandy silt, silt, clay, Pearlette ash, clay, silt and sandy silt which is overlain by massive caliche. Two faunas are known from these deposits. The older, the Cudahy fauna, occurs in the base of the Pearlette ash and the underlying silts, and is considered as latest Kansan in age. Frye, Swineford, & Leonard (1948) and Frye & Leonard (1952) have shown that the Cudahy molluscan fauna from the base and just below the Pearlette ash is the same in Nebraska and Kansas. It is therefore evident that the mammalian fauna should be the same in Kansas as in Nebraska except for a few more northern forms that may occur in the fauna in Nebraska. It is in this fauna that the remains of *Microtus* and other microtines are found. The species of *Microtus* that have been taken in this fauna are extinct. The small muskrat (*Ondatra kansasensis* Hibbard) occurring in this fauna is not as advanced or as large as *Ondatra nebracensis* (Hollister) from the Hay Springs fauna. The Hay Springs muskrat is also more advanced than the small *Ondatra hiatidens* (Cope) from the Port Kennedy Cave fauna of Pennsylvania (Hibbard, 1955).

The younger Borchers fauna occurring in the Crooked Creek formation is found above the Pearlette ash and is tentatively considered as Yarmouth in age. The two microtines known from this fauna are *Synaptomys landesi* Hibbard, and a small muskrat-like vole, not as advanced as the older *Ondatra kansasensis*.

The earliest occurrence of *Microtus pennsylvanicus* in the Plains region south of Nebraska is in the Illinoian Berends local fauna of Oklahoma and the Sangamon Jinglebob fauna of Kansas. It is well known from Wisconsin faunas. It should be noted that this vole which is now a common member of our northern North American fauna is unknown from the Port Kennedy Cave and Cumberland Cave local faunas of northeastern United States. All evidence at the present time points to a rather late arrival of this form in our North American fauna.

In Kansas the remains of *Microtus pennsylvanicus*, *Paramylodon harlani* (Owen) (see Stock, 1925, p. 120); *Mammuthus imperator* (Leidy), *Capromeryx furcifer* Matthew, and *Equus niobrarensis* Hay are known only from deposits that are post-Pearlette ash in age. Rinker (1949) commented on the resem-

blance of the Hay Springs fauna to the Cragin Quarry fauna and its equivalents in Kansas.

The Hay Springs local fauna of Matthew (1918) and Hay (1924) is post-Pearlette ash in age (late Kansan). All faunal evidence points to a late Illinoian and Sangamon age. In this paper the assignment of Pleistocene subages to the faunas and deposits in the nonglaciated Plains region is tentative.

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MANUSCRIPT RECEIVED MAY 7, 1956

REVISION OF THE TRILOBITE GENUS *MARYVILLIA* WALCOTT

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ABSTRACT—The genus *Maryvillia* Walcott, 1916, based on the type species *M. arion*, has been misinterpreted. It is shown to be a close relative of *Blountia*. A second species described by Walcott, *Maryvillia ariston*, is made the type of a new genus, *Coosina*. All the species assigned either to *Maryvillia* or *Coosina* and their synonymies are listed.

Walcott (1916) established the genus *Maryvillia* on the type species *M. arion* and also described a second species, *M. ariston*. Of each species both cranidia and pygidia were figured, the cranidia being designated as the respective holotypes.

Resser (1942a) believed that: (1), the cranidia of *Maryvillia arion* and *M. ariston* were congeneric; (2), the pygidia attributed to them by Walcott did not belong with the cranidia. He separated these pygidia under the respective names, *Blountia argula* and *B. angustata*. In a subsequent paper (Resser, 1942b) he described a number of species of *Maryvillia*, based on cranidia essentially identical with those of *Maryvillia ariston* combined with *Coosia*-like pygidia. This association was later verified beyond reasonable doubt by several authors, including the writer.

However, examination of the type material of all the relevant species convinced the

writer that Resser was mistaken in disassociating Walcott's cranidium and pygidium of *Maryvillia arion*. Since the latter is the type species of the genus, the characters of *Maryvillia* must be based on it. *Maryvillia* then turns out to be a trilobite closely allied to *Blountia*, and quite different from the concept of *Maryvillia* that has prevailed in recent years. A new name is therefore proposed for the trilobites typified by *Maryvillia ariston* which cannot be assigned to any described genus.

Examination of the holotype cranidium of *Maryvillia arion* shows that it cannot be considered even specifically different from *Protillaenus marginatus* Raymond, 1937, and *Blountina triangularis* Lochman, in Lochman & Duncan, 1944. Shaw (1952) recognized the generic identity of the two latter species and hence placed *Blountina* in synonymy with *Protillaenus*. It now turns out that both genera are synonyms of *Maryvillia*. The association of cranidia and pygidia for this trilobite was already proved beyond reasonable doubt by Lochman and Duncan for "*Blountina triangularis*." Search in the U. S. National Museum collections revealed the same association at locality 119, Bull Run, near Knoxville, Tennessee. The writer collected the same cranidia and pygidia in the Dresbachian beds of the Conococheague formation near Winchester, Virginia.

Walcott's second species, *Maryvillia ariston*, was indeed based on an incorrect association of cranidium and pygidium, as recognized by Resser. Walcott's pygidium differs so little from the pygidium assigned to *Maryvillia arion* that the writer does not hesitate to attribute it to that species. The cranidium and holotype of the species, however, is precisely the *Coosia*-like trilobite to which Resser correctly assigned a *Coosia*-like pygidium. For these forms, which now lack a name, the writer hereby proposes the genus *Coosina*.

In view of the confusion that has prevailed about these trilobites, it seems opportune to describe both the genera involved.

Maryvillia Walcott, 1916 [Type species *Maryvillia arion* Walcott, 1916, Smithsonian Misc. Coll., vol. 64, no. 5, p. 400, pl. 64, figs. 4–4c]. Glabella slightly tapered, rounded in front, unfurrowed, defined by a narrow and shallow dorsal furrow, not emerging above the general convexity of the cranidium; occipital furrow shallow, occipital ring very short (sag.). Preglabellar field steeply downsloping; anterior border wide (sag.), horizontal, flat, separated from the preglabellar field by a sharp change in slope rather than a furrow. Ocular ridges faint, straight; palpebral lobes small, not appreciably elevated, well anterior to glabellar midpoint, distant from glabella less than one-third of glabellar width. Anterior branch of facial suture directed almost straight forward from palpebral lobe, curving inward across border, marginal in frontal portion. Posterior branch curving gently backward to posterior margin, defining a sharply pointed, somewhat falcate posterior area; posterior border furrow well impressed.

Pygidium subtriangular, well rounded posteriorly, somewhat wider than long, with all furrows more or less obsolete on outer surface, shallow on interior casts. Axis narrow, reaching the posterior border, with 8–10 rings. Pleural lobes smooth or faintly furrowed on interior surface; border furrow shallow, border downrolled.

Maryvillia differs from *Blountia* chiefly in the shallowness of the dorsal furrow and lack of elevation of the glabella, almost parallel instead of divergent anterior facial sutures, and downrolled pygidial border.

The type species of *Blountina*, *B. eleanora* Lochman, is somewhat intermediate between *Blountia* and *Maryvillia* in the cranidial features, but on the whole seems better placed in *Maryvillia*, thus making *Blountina* a subjective synonym of that genus.

The species assigned to *Maryvillia* are:

Maryvillia arion Walcott, 1916. Synonyms: *Blountia angustata* Resser, 1942; *B. arguta* Resser, 1942; *B. widnerensis* Resser, 1942; *Blountina triangularis* Lochman, 1944; *B. westoni* Rasetti, 1946; *Protillaenus marginatus* Raymond, 1937.

Blountina eleanora Lochman, in Lochman & Duncan, 1944.

Coosina Rasetti, 1956 [type species *Maryvillia ariston* Walcott (part), Smithsonian Misc. Coll., vol. 64, no. 5, p. 401, pl. 64, figs. f,f′ (not 5a)]. Cranidium of very low general convexity. Glabella defined by a shallow and narrow dorsal furrow, tapered, rounded in front, unfurrowed, sometimes slightly keeled

on interior cast. Occipital furrow impressed; occipital ring of medium length (sag.). Anterior area poorly divided into preglabellar field and border by a wide, shallow, or even indistinct border furrow; border flat or slightly convex. Ocular ridges faint or indistinct; palpebral lobes of medium length, slightly elevated, somewhat anterior to glabellar midpoint. Width of palpebral area less than half the glabellar width. Anterior branch of facial suture directed forward and somewhat outward from palpebral lobe, turning inward in wide curve, marginal in frontal portion. Posterior branch curving backward, rounding off the end of the well-furrowed posterior area.

Pygidium wider than long, approximately semicircular. Axis averaging three-fourths of the pygidial length, defined by dorsal furrows faintly impressed on the outer surface but deep on the interior cast; extended into a postaxial ridge. Four or five axial rings, usually obsolete on outer surface, visible on interior cast. Pleural platforms convex, the convexity usually increasing toward the margin, unfurrowed except for the anterior furrow. Border furrow indistinct even on interior casts; border usually downturned, sometimes flat and wider (sag.) in the median portion, indicating a tendency to the expansion commonly observed in *Coosia* and *Coosella*.

Resser assigned to some of his species of "*Maryvillia*" now placed in *Coosina* a rounded, wide-bordered hypostome. The author, having no evidence either for or against this assignment, prefers to leave the characters of the hypostome out of the generic diagnosis.

Coosina is obviously a close relative of *Coosia* and *Coosella*, transitional forms to either genus being known. The main differences from *Coosella* are the shallower dorsal furrow, lesser relief of the cranidium, smaller palpebral lobes, and entirely convex pygidium. *Coosina* differs from *Coosia* mainly in the much lesser extent of the anterior area of the fixed cheeks and the pygidial border.

Examination of the types of Resser's species of "*Maryvillia*," now assigned to *Coosina*, showed that the differences between most of them are not greater than observed among a large suite of specimens of *Coosina ariston* collected by the writer from a single stratum; hence they must be ascribed to intraspecific variability. The most frequently variable characters in the cranidium are the degree of tapering of glabella, the presence or lack of a slight median keel on interior casts, the flat or slightly convex profile of the anterior border; in the pygidium, the elevation of the axis, the distinctness of the axial rings, the slope and width of the border. Some of Resser's species here placed in synonymy with *Coosina ariston* are represented by one or two poorly preserved specimens, insufficient to determine the precise specific characters. However, the writer believes that the burden of proof is on the author of a new species: when a specimen agrees with a previously described species in all the features that can be observed, no matter how few or inconclusive, it should be placed in that species; not considered a new species on the strength of differential characters that *might* be discovered if more and better-preserved specimens were collected. Failure to follow this elementary principle and to recognize the existence of intraspecific variability, led to the introduction of hundreds of meaningless names for Cambrian trilobites.

The species assigned to *Coosina* are:

Maryvillia ariston Walcott, 1916 (part). Synonyms: *M. georgica* Resser, 1938 (part); *M. keithi* Resser, 1938; *M. masadensis* Resser, 1938 (part); *M. widnerensis* Resser, 1938; *M. alberta* Resser, 1942; *M. marjumensis* Resser, 1942; *M. montis* Resser, 1942; *M. moosensis* Resser, 1942; *M. utahensis* Resser, 1942; *M. wyomingensis* Resser, 1942; *M. aequa* Duncan, in Lochman & Duncan, 1944; *M.* cf. *M. ariston* Walcott, in Palmer, 1955.

Maryvillia loperi Resser, 1942.

The following species described by Resser as *Maryvillia* do not belong either in that genus or in *Coosina*. *Maryvillia bristolensis* is fully typical of *Blountia;* so may be *M. violaensis*, as far as can be ascertained from the poor type material. *M. hybrida* was shown by Palmer (1955, p. 722) to be based on an illegitimate combination of a *Blountia* cranidium and a pygidium probably belonging to *Coosella*.

Palmer (1955) established a *Maryvillia* zone on the basis of species now assigned to *Coosina;* hence the proper name should be *Coosina* zone.

Blountia (with the subgenus *Homodictya*),

Blountiella and *Maryvillia* constitute a very homogeneous group of genera that are obviously closely related to and presumably descended from the late Middle Cambrian genus *Asaphiscus*. Hence their assignment to the subfamily Asaphiscinae of the family Asaphasicidae, suggested by Shaw (1952) and adopted by Palmer (1955), seems in order, making a family Blountiidae entirely unnecessary.

Coosina, being a close relative of *Coosia* and *Coosella*, would fall in the family Cooselidae as proposed by Palmer (1955). However, if *Crepicephalus* is included, the proper family name would be Crepicephalidae for priority reasons. Palmer's argument for the close relationship between *Crepicephalus* and *Coosella* is convincing, since the development of marginal pygidial spines, to which older taxonomists and, unfortunately, also recent ones attribute great importance, is at most of generic value as shown by numberless examples. Hence the writer is in favor of a family Crepicephalidae to include the genera *Crepicephalus*, *Coosia*, *Coosina*, *Coosella* and *Syspacheilus*.

Finally one may remark that the Asaphiscidae and the Crepicephalidae are not distantly related, since there are genera which partake of the characters of both groups. Probably one would not have to go farther back than the late Middle Cambrian to find plausible ancestors for both families in such ptychopariids as *Ehmania*, *Ehmaniella* and *Armonia*, from which the Asaphiscidae and the Crepicephalidae essentially differ only in the macropygous development.

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MANUSCRIPT RECEIVED MARCH 14, 1956

DISCOVERY OF THE CARLILE (TURONIAN) AMMONITE *COLLIGNONICERAS WOOLLGARI* IN NORTHWESTERN MONTANA[1]

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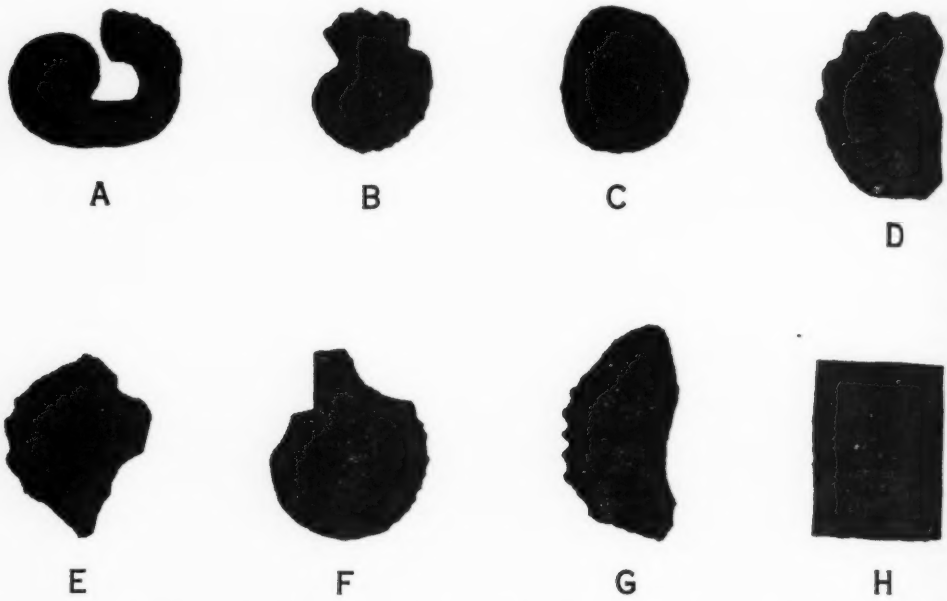
Ammonites of early Carlile age (middle part of Turonian stage of the Late Cretacous) were found by W. L. Rohrer during the summer of 1954 while engaged in detailed structural mapping in the Colorado shale on Kevin-Sunburst dome in northwestern Montana under the supervision of C. E. Erdmann. The ammonites, chiefly *Collignoniceras woollgari* (Mantell), were found near the top of a calcareous shale member. Previous fossil collections from this member have been of Greenhorn age (early Turonian). Although the possibility that the upper part of the calcareous member was of early Carlile age had been suggested (Cobban, 1951a, p. 2187, 2191), this is the first real evidence.

During the summer of 1955 W. A. Cobban found fossils of middle Greenhorn age at the very base of the calcareous member. In terms of the Greenhorn limestone and Carlile shale of the central Great Plains, the calcareous unit on the Sweetgrass arch is equivalent to the Bridge Creek limestone member (upper half of Greenhorn limestone) and to the Fairport chalky shale member of the Carlile shale. Inasmuch as there is a

[1] Publication authorized by the Director, U. S. Geological Survey.



TEXT-FIG. *1*—Rubber casts, ×1, of ammonites from Colorado shale 10 miles east-northeast of Shelby, Montana. *A*, *Scaphites larvaeformis* Meek & Hayden, adult; *B-E*, *Collignoniceras woollgari* (Mantell) var. *intermedium* Haas, juveniles; *F,G*, *Collignoniceras woollgari* (Mantell) var. *regulare* Haas, juveniles; *H*. *Collignoniceras woollgari* (Mantell), forma typica, juvenile.

tendency for geologists to refer to the calcareous unit on the Sweetgrass arch as Greenhorn, the new age assignment should clarify the meaning of that term as used in this area.

THE FOSSILS

The following fossils were collected at U. S. Geological Survey Mesozoic locality D137, 10 miles east-northeast of Shelby, along the bank of a coulee in the $N\frac{1}{2}NW\frac{1}{4}SW\frac{1}{4}$ and $SW\frac{1}{4}NE\frac{1}{4}SW\frac{1}{4}$ sec. 5, T. 32 N., R. 1 E., Toole County, Montana (Antelope Coulee 15-minute quadrangle).

Pelecypods:
- *Inoceramus* cf. *I. amudariensis* Arkhanguelsky

Ostrea sp. (small, simple form)

Cephalopods:
- *Scaphites larvaeformis* Meek & Hayden
- *Scaphites* cf. *S. patulus* Cobban
- *Collignoniceras woollgari* (Mantell)
- *C. woollgari* var. *intermedium* Haas
- *C. woollgari* var. *regulare* Haas

Fish scales and tooth:
- *Ichthyodectes* sp. (scales)
- *Squalicorax falcatus* (Agassiz)

Collignoniceras woollgari (Mantell) is a moderately evolute ammonite that has a serrated keel and, on the flanks, strong ribs that have nodes near their ventral ends. The ribs are forwardly inclined and somewhat curved on young individuals, and less inclined, straighter, and proportionally fewer on large specimens. Each rib bears near its ventral end a spirally elongated node (nearest the mid-line of the venter) and a conical node. The keel is notched to form a series of nodes each of which is asymmetric owing to its forward slope being steeper than that of the rear. There is one node on the keel for each rib on the flank.[2]

The species varies greatly in size, cross section, ornamentation, and suture line. It has been made the subject of a thorough study by Haas (1946) who subdivided the species into a forma typica and six named varieties. The forma typica and Haas's varieties *regulare* and *intermedium* can be identified in the collection from the Kevin-Sunburst dome. The forma typica (Text-fig. 1,H) is less involute than these varieties and has more widely spaced ribs. The variety

[2] *Prionocyclus*, the immediate descendent of *Collignoniceras*, has more than one node on the keel for each rib on the flank.

regulare (Text-fig. 1,F,G) has closely spaced ribs and small nodes. Occupying a position between these forms is the variety *intermedium* (Text-fig. 1,B–E).

Previous to 1946, *Collignoniceras woollgari* was recorded in the literature usually as *Prionotropis woolgari*. Haas (1946, p. 150) has pointed out the error in spelling *woollgari* with one "l" introduced by Meek (1876, p. 453, 455–457) and followed by all American authors until corrected by Muller & Schenck (1943, fig. 6). Haas (1948) has drawn attention also to the work of Breistroffer (1947) in which Meek's generic name *Prionotropis* was found to be preoccupied 23 years by a genus of Orthoptera. Breistroffer proposed the new name *Collignoniceras*.

The other ammonites, *Scaphites larvaeformis* Meek & Hayden (Text-fig. 1,A) and *S. patulus* Cobban, are known only from the level of *Collignoniceras woollgari* in rocks of early Carlile age (Cobban, 1951b, p. 20).

The figured specimens are deposited in the United States National Museum, Washington.

STRATIGRAPHIC POSITION

The fossils are impressions in dark-gray calcareous shale about six feet below the top of a calcareous member near the middle of the Colorado shale. This calcareous member is commonly 40 to 60 feet thick over most of the Sweetgrass arch. About 3.6 miles south of the fossil locality the top of the member is approximately 865 feet above the base of the Colorado shale in the Texas Company's Wallace Trustee No. 1 well in the NE¼SW¼ NW¼ sec. 29, T. 32 N., R. 1 E. Outcrops of the calcareous member are few and very poor on the Kevin-Sunburst dome. On the South arch, where the member is well exposed, a 3-foot bed of white bentonite divides the member into a lower slightly calcareous unit and an upper very calcareous unit. Along Muddy Creek south of Power the lower unit consists of about 14 feet of dark-gray slightly calcareous to noncalcareous shale that contains closely spaced gray septarian calcareous concretions at the base and much smaller gray limestone concretions at the top. Fossils from the base and top include the ammonite *Sciponoceras gracile* (Shumard) which dates this part of the member as middle Greenhorn (equivalent to basal part of the Bridge Creek limestone member in the central Great Plains). The upper unit, about 27 feet thick, is mostly calcareous shale and chalk marl but includes some hard thin lenses of gray limestone and thin layers of white bentonite. It contains *Inoceramus labiatus* (Schlotheim) from the base to within a few feet of the top of the unit. This pelecypod is abundant in and restricted to the upper part of the Greenhorn limestone of the central Great Plains.

Over the entire Sweetgrass arch area the calcareous member is bounded below and above by dark-gray noncalcareous shale. The contacts are very sharp and commonly marked by limonite and, in places, by shark and skate teeth as well. Locally, a few black chert pebbles as large as ½ inch in diameter may be present along the upper contact.

In the subsurface the calcareous member is easily recognized by abundant minute white specks, bits of limestone, fish bones and scales, and by a characteristic "kick" on electric logs. Over much of the western interior of Canada this calcareous member is known as the Second Speckled shale (Goodman, 1951, p. 2427).

DISTRIBUTION OF *Collignoniceras woollgari* IN THE WESTERN INTERIOR

Collignoniceras woollgari (Mantell), originally described from chalk of Turonian age in England (Mantell, 1822, p. 197), is widely distributed in the western interior of the United States. In east-central Montana *C. woollgari*, *Scaphites patulus*, and a small oyster occur together in a 12-foot unit of noncalcareous shale that weathers orange brown and lies about 700 feet below the top of the Colorado shale (Cobban, 1951, p. 2190). On the north flank of the Black Hills uplift in the vicinity of the common corner of Montana, Wyoming, and South Dakota, *C. woollgari* occurs in limestone concretions near the base of the Carlile shale (Cobban, 1951, p. 2188). There it is associated with the ammonites *Scaphites larvaeformis* Meek & Hayden, *S. patulus* Cobban, *S. praecoquus* Cobban, *Borissiakoceras*, *Tragodesmoceras*, and *Proplacenticeras*. Other associates include *Inoceramus fragilis* Hall & Meek and the same small oyster found at Mosby and on the Kevin-Sunburst dome. *Inoceramus fragilis* Hall & Meek occurs with *C. woollgari* over much of the central Great Plains. The piece of shale containing the

holotype of *Inoceramus fragilis* has in addition several impressions of *C. woollgari* (Stephenson, 1952, p. 64, pl. 12, fig. 3). It was found near the mouth of the Vermilion River in southeastern South Dakota or northeastern Nebraska. In central Kansas *C. woollgari* and *I. fragilis* occur together in the Fairport chalky shale member of the Carlile shale (Rubey & Bass, 1925, p. 41). Bass (1926, p. 66) records them also from the Fairport chalky shale member in southwestern Kansas. Farther west Dane, Pierce, & Reeside (1937, p. 220) found *C. woollgari* in the Fairport of the Arkansas River area in southeastern Colorado. *Collignoniceras woollgari* is not known with certainty in a large area extending from north-central New Mexico north and northwest through central Colorado and central Wyoming. West of this area *C. woollgari* is known from many localities. Pike (1947, p. 22, 27, 46) found the ammonite in the lower part of the Mancos shale of the San Juan Basin in northwestern New Mexico, and Reeside & Baker (1929, p. 34–35) record it from the Mancos shale in the Black Mesa Basin of northeastern Arizona. In the Wasatch Plateau area of central Utah *C. woollgari* has been collected from the upper part of the Tununk shale member of the Mancos shale (Katich, 1954, p. 46). Farther north the species occurs in the Oyster Ridge sandstone member of the Frontier formation in north-central Utah and southwestern Wyoming (Cobban & Reeside, 1952, pp. 1924, 1925, 1932, 1936). It has been found also near the middle of the Frontier formation in the Jackson Hole region (Love et al., 1951).

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MANUSCRIPT RECEIVED APRIL 20, 1956

AN UNUSUAL WORM TUBE FROM THE LOWER LIAS

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University College, London

ABSTRACT—A description is given of a worm tube almost entirely lined with tests of Foraminifera. The specimen possibly represents a marine worm of the polychaete family Amphicteridae.

Accounts have been given in the past of fossil worm tubes lined with shell fragments (chiefly lamellibranch or gastropod), mineral flakes, and fish scales, but as far as the author is able to ascertain, a tube lined almost entirely with the tests of Foraminifera has not so far been recorded or described.

The author wishes to acknowledge Mr. R. V. Melville who discovered the worm tube, and thank him for allowing it to be described.

The thanks of the author are also due to Mr. Teble, who not only read the manuscript, but made helpful suggestions.

The remnant of the tube was discovered in a core from the lower Lias (*davoei* zone: *lataecosta* sub-zone) of the Stowell Park boring, near Northleach, Gloucester, depth 892 ft. 11 in. (Survey Number 91732).

The almost straight, slightly compressed remnant of the tube is 38 mm. long, and has a diameter of 6 mm. There are about 5,000 tests of Foraminifera making up the tube, one ostracod belonging to the genus *Bairdia*, two small calcite flakes and one mica flake. The Foraminifera are packed tightly with their long axes parallel; where a little space does occur between them, a different colored binding material is seen. There is little variation in the size of the tests of the Foraminifera, from about 0.8 mm.–1.2 mm. in length and about 0.2 mm. in diameter. Three species of Foraminifera make up the test: *Lenticulina matutina* d'Orbigny and *Dentalina terquemi* d'Orbigny, both smooth forms, together with *Dentalina matutina* d'Orbigny, a species having longitudinal striations. The majority of specimens of *Lenticulina matutina* d'Orbigny are forms having several chambers in the rectilinear portion of the test, only very few are composed entirely of the initial spire.

TEXT-FIG. 3—An enlarged portion of the tube showing the restricted number of species of Foraminifera, their orientation and closeness of packing, ×8.5.

The core at this level consists of a fine grained micaceous silt, with grains smaller than the tests of the Foraminifera. Contained in the rock are fragments of the lamellibranchs and gastropods, larger than the Foraminifera. Apart from the Foraminifera contained in the tube, no others were observed in the matrix, and a channel sample of 20 feet of core, 10 feet above and below 892 ft. 11 in. shows Foraminifera to be rare.

Among Recent marine Polychaete worms, the habit of building tubes is common, and is by no means confined to the sedentary forms. In later stages of ontogeny, individuals of the genus *Owenia* have a tube composed of two layers, an inner layer of mucus and an outer layer composed of sandgrains. Most of the tube-building polychaete worms

have either a tube made of a leathery "skin," or an irregular tube with an external layer of grains of different size and material.

A notable exception to this is the marine worm *Pectinaria belgica* (Pallas), family Amphicteridae, order Polychaeta, which forms a tapering tube of almost equidimensional sand grains. This form resembles very closely the fossil worm tube described above.

Worms belonging to the family Amphicteridae live completely buried in the sand, in a tapering conical tube, open at both ends, the wide end directed downwards.

The tapering fossil tube with its peculiar architecture suggests that it may have been made by a worm of the family Amphicteridae and, if this is the case, then the recording from the lower Lias extends back the record of fossils belonging to this group.

SOCIETY RECORDS AND ACTIVITIES

In accordance with Article 3, Chapter 1 of the By-Laws of the Paleontological Society, the Secretary submits the following nominations for membership in the Society. The list has been approved by the Council of the Society.

CAMPBELL, KENTON STEWART WALL, Geol. Dept., Univ. New England, Armidale, N.S.W., Australia: Kenneth E. Caster, A. Öpik, H. B. Whittington.

HAINER, JOHN LINTON, c/o Shell Oil Company, Melrose Building, Houston, Texas: F. D. Holland, Jr., Wilson M. Laird.

LEBLANC, ARTHUR E., Shell Oil Company, P.O. Box 1509, Midland, Texas: George A. Sanderson, Jr., Jesse B. Pogue, II, James M. Parks, Jr.

LOVEJOY, BILL P., Shell Oil Company, P.O. Box 1509, Midland, Texas: George A. Sanderson, Jr., Jesse B. Pogue II, James M. Parks, Jr.

PERRY, NORTON R., c/o Standard Oil Company of Texas, P.O. Box 1249, Houston, Texas: Paul R. Beach, C. M. Quigley, Jr.

PHILIP, GRAEME MAXWELL, c/o Dept. Geol., Univ. Melbourne, Melbourne, Australia: E. D. Gill, K. E. Caster, John A. Talent.

POLUGAR, MORTON, c/o Dominion Oil Ltd., 29 St. Vincent St., Port of Spain, Trinidad, B.W.I.: H. B. Whittington, Richard Cifelli.

RUTSCH, R. F., Melchenbuhlweg 75, Bern, Switzerland: H. B. Whittington, Richard Cifelli.

REVIEW

DER GROSSABLAUF DER STAMMESGESCHICHTLICHEN ENTWICKLUNG, Arno Hermann Müller, 50 p., 25 fig., Geb. Gustav Fischer Verlag, Jena, 1955.

This interesting and useful inquiry into broad patterns of phyletic evolution was stimulated by a symposium on explosive evolution published in the Journal of Paleontology in 1952 (Henbest, et al., 1952). Professor Arno Hermann Müller, of the University of Jena, has carefully surveyed the known fossil record of better known animals from which he draws some interesting conclusions about taxonomic rates and patterns of evolution.

His mode of attack involves the graphic representation of counts of known genera and higher categories at successive horizons through the stratigraphic column, a method now familiar to most paleontologists through studies of Simpson, Rensch, and others, but he has added an interesting modification which constitutes the main contribution of his work. The mathematical results are shown in a series of bilaterally symmetrical graphs similar to the stratigraphic range and abundance charts employed by paleontologists for many decades. Within the area covered by each graph, fossil genera are grouped by patterns according to total range in years. Thus, the reader can see at a glance the proportion of long ranging, intermediate, and short ranging genera known to exist at a particular epoch. Müller has devoted his attention to those groups for which he bebelieves the record adequate for this kind of analysis: trilobites, nautiloids, ammonoids, brachiopods, Foraminifera, echinoids, fishes, amphibians, reptiles, and mammals. From the tabulations are derived statistics on the average duration of genera and higher categories.

Müller's original handling of his raw data has enabled him to recognize three phyletic patterns which are characterized as follows:

Regressive type, illustrated by the trilobites and the nautiloids. There is a succession of bursts of evolutionary activity which are of progressively decreasing intensity and duration. The maximum diversity of each of these successive phases occurs at the beginning of the stage and was represented mainly by short-lived genera. Single-phase diversification characterizes families (*e.g.*, Manticoceratidae) and superfamilies.

Progressive type, illustrated by fusulines and clymeniids (early goniatites). The forms that show this phyletic pattern experience successive phases or bursts of diversification which show increasing intensity and duration. The maximum diversity of each lies at the close of the phase and comprises mainly genera of short range. Müller does not discuss the possibility that the successive bursts in this and the preceding type may be artifacts of the known record. That is, the intermediate stages between bursts may be filled eventually by discovery. It is also possible, or even probable, that oscillations of the epicontinental seas may correlate with his successive phases.

Intermediate type, illutrated by brachiopods and amphibians. Among these forms the times of taxonomic expansion are clustered in larger periods of flowering (Virenzperioden) in which there is a weak initial phase, a strong climatic phase, and a weak terminal phase. Individual phases may resemble the regressive or progressive types.

The hypothetical factors responsible for the observed patterns are discussed only very briefly, but Müller indicates that he is attracted to Schindewolf's hypothesis that endogenous factors and cosmic radiation control the general course of evolution, whereas the immediate ecological situation has only modelling effects through natural selection. It appears to me that Müller places greatest emphasis on gene mutation as the directional force in evolution and assigns a very subordinate role to selection. This does not accord with the prevalent view among students of population genetics that direction in evolution is brought about almost entirely by environmental factors, both biotic and physical. Acceleration of mutation by erratic bursts of cosmic radiation as suggested in this hypothesis could not by any known mechanism bring about evolutionary trends such as those described by Müller. It is difficult to see how this could result in taxnomic expansion at the generic level, unless one appeals to the unproved and improbable theory that genera characteristically spring into being suddenly as result of single mutations.

It seems to me that much more emphasis should be placed on biotic environmental

factors in evolution. The trilobites and nautiloids, on one hand, were gradually and uniformly replaced in time by the fishes (Newell, 1952, p. 381). Certainly these animals were in active mutual competition for ecological niches. How can we doubt that competition was one of the significant factors leading to decline of the two invertebrate groups and the rise of the fishes? Müller does not record the proportions of newly developed to surviving genera at successive horizons. Fluctuations in this ratio surely reflect changes in the tempo of evolution wherever the raw data are reliable.

From the very nature of the case, the validity of Müller's conclusions cannot be tested, nor can the adequacy of the paleontological evidence on which these conclusions rest be satisfactorily assessed. Although most paleontologists would agree that the record is surprisingly good, no one is prepared to say just how good it is. Attention has been frequently drawn to the unevenness in the record, a systematic deficiency which stems from erratic sampling and from regional variations in deposition and preservation. As a result, impressive objections have been raised to studies, such as this, based solely on taxonomic criteria gleaned from a largely unevaluated literature (Cooper & Williams, 1952; Gregory, 1955). Nevertheless, I believe that periodic surveys of the known record are valuable inventories of existing knowledge, and it cannot be denied that they stimulate thought and further investigation.

The final purpose of paleontology, apart from the more limited and mainly empirical contributions to stratigraphy, is the advancement of knowledge about the history of life. This knowledge is not obtained by means of controlled experiment but by exacting and difficult analyses of paleontological samples from which all inferences about past life must be drawn.

Appreciation of the role of fossils as statistical samples is now impelling paleontologists to familiarize themselves with statistical theory and techniques in order the better to evaluate the meaning and limitations of the fossil record. It seems that debate over the adequacy or inadequacy of the fossil record has very little meaning unless we examine the nature of the conclusions that are to be drawn from the sample.

It is interesting to note that independent tabulations of the frequency of fossil genera in better known groups tend to give the same general results. For example, my calculations, based on 795 genera (Newell, 1952, p. 378), the one by Cooper & Williams (1952, p. 332), based on 1,200 genera, and that by Müller, based on 956 genera all show peaks of diversity during the middle Paleozoic and lows in the Triassic and Cretaceous. Intensive work on Mesozoic brachiopods may or may not reduce this disparity, but I venture to express a doubt that there are any undiscovered Mesozoic brachiopod faunas that match the abundance and diversity of Silurian and Devonian forms. Müller's tabulation of trilobites, with 996 genera, and mine (Newell, 1952, p. 381) with 1,094 genera, provide the same general pattern of "regressive" evolution. Closely similar results were obtained with nautiloids, ammonoids, foraminifera, echinoids, fishes, amphibians, reptiles, and mammals (Newell, 1952; Simpson, 1952). This, of course, does not demonstrate the reliability of the raw data, but merely that we are interpreting available data in about the same way. It does seem highly improbable, however, that another hundred years of fossil collecting and taxonomic revision will appreciably alter the broad outlines in the nautiloids, ammonoids, trilobites, and Foraminifera. The slump in the brachiopods and bryozoans at the close of the Paleozoic, and the crises among the ammonoids at the end of the Permian, Triassic, and Cretaceous periods were real events which additional collecting tends to confirm.

Müller is to be congratulated on this stimulating work and it is hoped that others, especially taxonomic specialists, will undertake repeated tabulations of the fossil record.

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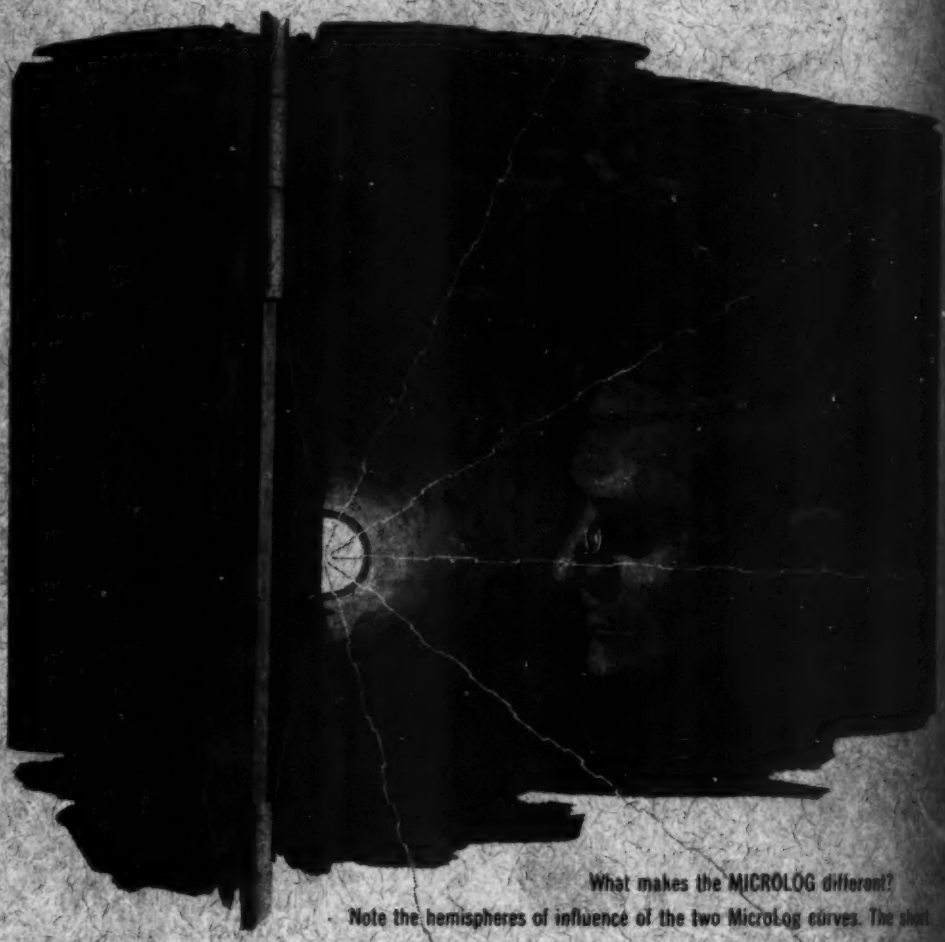

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